THE POPULATION DYNAMICS, REPRODUCTIVE BIOLOGY AND GEOGRAPHIC DISTRIBUTION OF *Boreomysis nobilis* G.O. SARS 1879 IN COASTAL FJORDS OF NEWFOUNDLAND, CANADA

KIRSTEN JANE CLARK, B.Sc.Hon.

The Population Dynamics, Reproductive Biology and Geographic Distribution of *Boreomysis nobilis* G.O. Sars 1879 in Coastal Fjords of Newfoundland, Canada

by

© Kirsten Jane Clark, B.Sc. Hon.

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Department of Biology
Memorial University of Newfoundland
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Abstract

The hyperbenthic mysid, *Boreomysis nobilis* G.O. Sars 1879, is reported from nine new locations around the island of Newfoundland in eastern Canada. It is most common within and at the mouths of deep fjords and is less common or absent outside these fjords. Its absence from two bays where the depths, temperatures and salinities are all within the range inhabited by *B. nobilis* in other bays indicates that other factors are likely influencing local distribution patterns.

Boreomysis nobilis breeds throughout the year, since all developmental stages were present on all sampling dates. However, there is a period of increased breeding activity in the late spring and early summer. An examination of the relationship between brood size, body volume of ovigerous females, and number of stage 1 larvae ("eggs") indicates that *B. nobilis* produces a smaller number of larger eggs than is predicted by the regression calculated for epipelagic and coastal mysids by Mauchline (1980). This agrees with the conclusion of Wittmann (1984) for epipelagic cold-water species of mysids. Thus *B. nobilis* exhibits a more K-selected strategy than its epipelagic counterparts from warmer water.

The catch rates for *B. nobilis* are highest in the deep water within 150m of the bottom. However, no differences are found in the vertical distribution of the different life history stages of *B. nobilis* and no evidence is found for large-scale diel vertical migrations.

The parasite *Thalassomyces boschmai* (Nouvel 1954) is reported from *B. nobilis*

and from Newfoundland waters for the first time. Its localized distribution in two bays is suggested to be a result of the restricted geographic distribution pattern of its host.

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Introduction

Mysids occur in large numbers throughout the marine environment (Mauchline 1980). The Mysidacea belong to the division Peracarida of the subclass Malacostraca. Characteristics of the division Peracarida include the fusion of one true thoracic segment to the head and the possession of an oöstegite brood pouch (Russell-Hunter 1969, Bousfield 1973).

Many marine animals are known to be predators of mysids. Fish, in particular, are considered important predators (Haedrich and Henderson 1974, Mauchline 1980, Astthorsson 1984, Houston and Haedrich 1986), while seals and birds are also known to eat mysids (Dunbar 1941, 1942, McLaren 1958, Sergeant 1973, Sanger 1987). Mysids themselves are important predators of other planktonic organisms including decapod shrimp (Daly and Holmquist 1986). However, most mysids are omnivorous, feeding on everything from detritus, to algae and copepods (Clutter 1967). The diet of *Boreomysis nobilis* appears to consist largely of non-calanoid crustacea (Wright 1972).

The type specimen of *Boreomysis nobilis* G.O. Sars 1879, a male 60 mm long, was collected at Spitsbergen in Norway (Sars 1879). In the original description, *B. nobilis* is a large mysid which is partially pigmented a rich red colour; it possesses a long, pointed rostrum with angled sides (Sars 1879)(Figure 1). *Boreomysis nobilis* is hyperbenthic (Wright 1972). It has been collected from Point Barrow, Alaska; the

Beaufort Sea and Barrow Strait; northern Baffin Bay; and from western Greenland to Spitsbergen (Sars 1879, Stephensen 1933, Tattersall 1939, Dunbar 1940, Banner 1954, Wright 1972, Shih and Laubitz 1978). It has also been found in the stomachs of cod caught south and west of Iceland (Astthorsson 1985). The temperatures and salinities at which the mysids were caught were not always recorded, but in studies where they were reported, temperatures ranged from -0.4°C to 4°C and salinities ranged from less than 34 parts per thousand (ppt) to 34.9 ppt (Dunbar 1940, Stephensen 1933, Wright 1972, Shih and Laubitz 1978).

Boreomysis nobilis has rarely been encountered in eastern Canadian waters south of the Arctic Circle. It has been reported from Newfoundland waters in Bonne Bay (Wright 1972), the Bay of Islands and the Bay of Exploits (Tattersall 1939), Fortune Bay and Belle Bay (Richard 1987, Richard and Haedrich 1991). *Boreomysis nobilis* has also been collected from the Saguenay Fjord in the St. Lawrence Estuary (Judkins and Wright 1974)(Figure 2). In each instance, the fjords in which *B. nobilis* were collected were deeper than 200 m and the water was 0°C or colder. The presence of *B. nobilis* in the deep eastern arm of Bonne Bay, and its absence from the Laurentian Channel and Gulf of St. Lawrence, led Wright (1972) to speculate that *B. nobilis* is a cold-water species which is probably restricted to the Arctic-like waters of coastal fjords in southeastern Canadian waters. This is supported by Richard (1987), who found *B. nobilis* in Fortune Bay, although it was absent from the Laurentian, St. Pierre and Hermitage Channels. *Boreomysis nobilis* was also absent

from the adjacent Bay d'Espoir where the deep water is relatively warm (4°C to 6°C)(Richard 1987). Judkins and Wright (1974) found that *B. nobilis* was common in the cold, deep waters of the Saguenay Fjord, but was absent from the St. Lawrence Estuary and the Gulf of St. Lawrence.

Most species of Mysidacea live in close association with the ocean bottom (Fössa 1985, Kaartvedt 1985). Diel vertical migration patterns have been described for several species (e.g. *Leptomysis gracilis* and *Lophogaster typicus*: Kaartvedt 1985, and *Boreomysis megalops*: Attramadal *et al.* 1985). In addition to these patterns, the different life history stages of a species of mysid may exhibit differential vertical zonation, with the juveniles occupying a different water layer than the adults (Clutter 1967, Fössa 1985, Kaartvedt 1985). Diel variations in the vertical zonation patterns have also been reported (Kaartvedt 1985). No studies have been conducted on the vertical zonation patterns of the life history stages of *B. nobilis*, and little is known of its vertical distribution beyond that it appears to be hyperbenthic and is found deeper than 200 m.

Studies have been made of the life histories of a large number of mysid species (see Mauchline 1980). Regular seasonal fluctuations have been observed in the composition of mysid populations and Mauchline (1980) postulates that the major cause of these seasonal fluctuations is reproductive patterns. Length-frequency distributions are often used when examining mysid populations. The appearance of separate modes in the length-frequencies may be interpreted as size classes

(MacDonald and Pitcher 1979), and when these modes are examined in detail over a period of time, they may show differences in the composition of the population based on size, age or stage of development. These differences in population composition may then indicate the existence of seasonal peaks in reproduction. Wright (1972) and Dunbar (1940) constructed length-frequency histograms for *B. nobilis* from Bonne Bay, Newfoundland and Ata Sound, Greenland respectively. Wright's histograms were based on collections from July and September 1970, and Dunbar's on samples collected in late July and early August. From such limited sampling little can be interpreted, but the bimodality of his histograms led Wright (1972) to speculate that two year classes were present in Bonne Bay, and that *B. nobilis* has a two year life cycle.

Mysids carry their embryos in a marsupium and thus brood size and brood development can be observed directly. All larvae in a brood pouch are at the same stage of development. Occasionally an older larva may be found in a brood of younger larvae, but this is thought to result from adoption (Mauchline 1980). The number of larvae in the marsupia of many species of mysids decreases as they develop (Amaratunga and Corey 1975, Wittmann 1984); this brood mortality may range up to 20% (Mauchline 1973).

Epipelagic mysids are defined as those mysids living in shallow coastal environments, those that live at depths down to 500m on the sea bottom in coastal and continental shelf areas and those that live in the surface layers of oceanic areas.

Mesopelagic mysids live at depths ranging from 300m to over 1000m, and bathypelagic mysids live at depths greater than 1000m (Mauchline 1972). According to this definition *B. nobilis* from coastal fjords south of the Arctic Circle are epipelagic. Mauchline (1980) observed that meso- and bathypelagic species of mysids tend to produce fewer, larger eggs relative to their body size than epipelagic and coastal species. Wittmann (1984) re-examined this relationship, and found that epipelagic, cold-water breeders conform with meso- and bathypelagic breeders, producing larger eggs relative to their body size than their warm water epipelagic and coastal counterparts. The reproductive biology of *B. nobilis* has not been studied, but the fact that it is an Arctic species found in cold water, suggests it would exhibit a reproductive strategy similar to the meso- and bathypelagic mysids.

Although mysids are frequently encountered in plankton tows, their parasites and pathological conditions, particularly in the western North Atlantic, have not been extensively studied (Mauchline 1980). Helminth endoparasites and crustacean ectoparasites have been recorded from several mysid species (e.g. Tattersall and Tattersall 1951, Brownell 1970, Amin 1978, Daly and Damkaer 1986), but the most frequently reported parasite is the protozoan *Thalassomyces* spp. (Ellobiopsidae) (Mauchline 1980). This parasite tends to prevent the maturation of the reproductive organs of euphausiids, but its effect on the reproductive system of mysids is unknown (Mauchline 1980).

Boreomysis nobilis has been found in large numbers in the deep fjords around

Newfoundland, yet its biology is virtually unknown. Previous reports of its geographic distribution have suggested that it is restricted to cold, deep fjords. My study was undertaken to determine if this is the case, and to determine the extent of the mysid's distribution in Newfoundland waters. The population characteristics, vertical distribution and reproductive biology of *B. nobilis* are of particular interest since it is an organism at the southern extreme of its range, with an unusual geographic distribution. A comparison of the biology of this mysid to that of other epipelagic and coastal mysids should indicate the life history strategy that an isolated population of cold water mysids employs. Parasites are an important aspect of the biology of any host because of their potential effect on the reproductive capability and fitness of the host. My study examines the parasites, distribution, population characteristics and reproductive biology of *B. nobilis* and compares these features to those of other species of coastal and cold water mysids.

Materials and Methods

2.1 Sampling Procedure

One hundred and five samples were collected around the west and northeast coast of Newfoundland during four scientific cruises in 1986 and 1987. Sampling locations are shown in Figures 3 to 5 and sampling locations, depths, temperatures and salinities are shown in Tables 1 and 2. The cruise Dawson 86-026 was conducted on the Canadian Survey Ship Dawson in September 1986. The cruise Templeman-54 was the fifty-fourth research trip of the Research Vessel W.T. Templeman; it occurred in November 1986. In May 1987, the cruise Baffin 87-016 was conducted on the C.S.S. Baffin, and in August 1987, the cruise Dawson 87-030 was conducted on the C.S.S. Dawson (Table 3).

Three types of sampling devices were used in this study: a 10 foot Isaacs-Kidd Midwater Trawl (IKMT), a six foot IKMT, and bongo nets (Figure 6). The bongo frames were 61 cm in diameter and the nets that were attached to the frames had a mesh size of 330 μm. The IKMT, designed for sampling pelagic marine organisms (Isaacs and Kidd 1953), consisted of a net with a large mouth which was kept open by a spreader bar and a heavy depressor. The ten foot IKMT had a spreader bar which was ten feet long, whilst that of the six foot IKMT was six feet long. In this study the IKMT nets had a 10 mm stretched mesh liner and a cod end mesh of 0.47 mm.

The type of nets that were used on each cruise depended upon their availability since all nets were borrowed from the Scotia-Fundy and Newfoundland Regions of the Department of Fisheries and Oceans. The ten foot IKMT was used for all twenty-two samples collected in August 1986. A six foot IKMT was used when the weather was too rough to use bongo nets in November 1986; it collected sixteen out of forty-one samples. The remaining twenty-five samples from November 1986 were collected with the bongo nets. As a result of technical difficulties, the ten foot IKMT could only be used to collect three out of twenty-two samples in May 1987; the other nineteen samples were collected with bongo nets. Six samples were collected with the ten foot IKMT and fourteen with the bongo nets in August 1987 (Table 3). In addition to these samples, 44 ovigerous *B. nobilis* females were examined from three stations in Fortune Bay; these samples were collected in May 1982 and June 1983 using a ten-foot IKMT (Table 4). The Fortune Bay samples were used in the examination of the relationship between body length and brood size, egg volume and egg number, and in the examination of broods for evidence of adoption. Seven hundred and seventy *B. nobilis*, including all six life history stages were collected from seven sampling locations (stations) in Fortune Bay and were examined for parasites (Table 4).

All tows using the ten and six foot IKMT nets were horizontal. In November 1986, all tows using the bongo nets were oblique. Both oblique and horizontal tows were conducted with the bongo nets in May and August 1987 (Tables 1 and 2).

Horizontal tows ranged from thirty to seventy-five minutes and oblique tows from thirteen to forty-three minutes in duration. The time between the cessation of the paying out of the wire and the hauling of the net onto the deck was considered to be the length of fishing time. The ship speed was between 2.0 and 2.5 knots whilst the nets were being towed, and the speed at which the nets were retrieved varied from ten to fifty metres per minute. A Benthos® time-depth recorder (model number 1170-1000) was used to record the sampling depths in August 1986, November 1986 and May 1987. A VEMCO® hydroacoustic telemetry system, the transmitter of which was attached to the nets (Figure 6), and a VR-60 receiver were used to collect temperature and depth data in May and August 1987. Conductivity and temperature profiles were recorded in the vicinity of all sampling locations using a Mark IV CTD probe (Neil Brown Instrument Systems Inc.).

Entire samples were preserved in 4% formaldehyde in seawater buffered with borax, and were later transferred to 70% ethanol in the laboratory. Wet weights were taken by sieving the samples and blotting the bottom of the sieve with absorbent paper towel. When excess fluid had been removed, the samples were weighed on a Mettler PS-3600 balance. Samples were then rough-sorted and all mysids were extracted. *Boreomysis nobilis* were identified from the criteria of Sars (1879) and Tattersall (1951), and from information supplied by Dr. D. Laubitz of the National Museum of Canada. They were separated from the other species of mysids and were weighed using the same method described above. The percentage of the

wet weight of the whole sample that was comprised of *B. nobilis* was then calculated. Catch rates were calculated by dividing the number of *B. nobilis* caught per minute of towing by the mouth area of the net used (mysids per minute per m^2).

Boreomysis nobilis were divided into six different classes depending on the degree of development of the secondary sexual characteristics. These six classes, taken from the classifications of Mauchline (1980) and Beck (1977), were:

1. Juveniles - no secondary sexual characteristics
2. Immature males - secondary sexual characteristics in the process of developing
3. Mature males - secondary sexual characteristics fully developed
4. Immature females - oöstegites poorly developed, no brood
5. Ovigerous females - marsupium filled with embryos
6. Empty or spent females - empty marsupium from which young have emerged.

Specimens were counted and total length was measured to ±0.05 mm using Mitutoyo hand-held dial callipers and a Wild M-5 stereomicroscope. Total length was defined as the distance from the distal end of the rostrum to the distal tip of the telson (Mauchline 1980).

The stereomicroscope was used in the examination of the marsupia of ovigerous females and it was determined whether the brood pouches were intact or damaged (torn or displaced brood lamellae). The larvae were divided into three stages which corresponded to the three moults that the larvae undergo (Mauchline 1980). These stages were "eggs" or stage 1 larvae, "eyeless" or stage 2 larvae, and "eyed" or stage

3 larvae (Mauchline 1973, 1980). Marsupia were examined to see if they contained larvae of more than one developmental stage, and the orientation of stage 2 and 3 larvae in the full brood pouches was noted. The number of larvae in each brood pouch was determined, and with the exception of samples collected in August 1987, larvae were measured at 160X magnification using an eyepiece micrometer mounted on the Wild M-5 stereomicroscope.

The presence of helminth parasites in invertebrates such as euphausiids, may be indicated by a deposition of melanin in the vicinity of the parasite (Komaki 1970). All *B. nobilis* were examined for unusual pigmentation and for external parasites. *Thalassomyces boschmai* (Nouvel 1954) was identified using the keys of Wing (1975) and Kane (1964). The thoracic region of infected *B. nobilis* was dissected under the stereomicroscope to determine the structure of the primary stalk and the organ of fixation. Five specimens of *B. nobilis* infected with *T. boschmai* were examined using a scanning electron microscope.

2.2 Statistical Analysis

SAS programs on a VAX computer (SAS Institute, 1985), and Lotus 1-2-3 (Lotus Development Corporation, 1990) were used to conduct statistical tests on data collected for this study. Standard deviations (S.D.) were calculated for all mean values; these values are expressed in the text of this thesis as the mean ± the

standard deviation (e.g. mean temperature at which *B. nobilis* was caught = -0.3 ± 0.1°C). A one-way analysis of variance (ANOVA) was used to test whether the mean length of *B. nobilis* varied with the type of net used, and then a Scheffe's multiple contrast test (Zar 1984) was used to determine if the catches of the three types of nets were significantly different from each other. Chi-squared tests were used to determine whether the selectivity of the nets for different size ranges had an effect on the ratio of sexes caught, and a one-way ANOVA was used to compare the mean length of *B. nobilis* caught by oblique and horizontal tows. One way ANOVAs were used to examine the difference with depth in the percent of the sample wet weight that *B. nobilis* comprised, the difference in catch rates of the life history stages with depth, and the depth distribution of the mysid in relation to the time of day (day versus night). Histograms of length-frequency and of the percent frequency of the different life history stages were constructed for samples collected at three different times of the year in White Bay so that seasonal comparisons could be made.

In the examination of the broods of ovigerous females, chi-squared tests were used to compare the number of intact and damaged marsupia collected by the ten foot IKMT net and the bongo nets, and to examine the percent frequency of ovigerous females carrying the three different larval stages at different times of the year. A one-way ANOVA was used to test the significance of the variation in brood size at different times of the year. A regression line was calculated for the relationship between brood size and the cube of the total body length of ovigerous

females and the significance of the regression coefficient was determined using the tables in Zar (1984).

Glossary

Bathypelagic - organisms living at depths of 1,000 to 6,000 m (Mauchline 1972) adjacent to the ocean floor.

Bongo Nets - two nylon mesh nets which are fished side by side from a metal frame; the frame consists of two circular metal cylinders to which the nets are attached (Figure 6).

Brood Pouch - a chamber formed by the brood lamellae below the thorax of a mature female mysid. The embryos are carried in this chamber throughout their larval development (Mauchline 1980). The brood pouch is also referred to as a marsupium.

Cod End - the distal portion of a bongo net or IKMT where the catch is concentrated as the net is towed through the water (Figure 6).

Epipelagic - organisms living at depths of 0 to 500 m (Mauchline 1972) adjacent to the ocean surface.

Gonomere - a distal segment of a trophomere of the parasite *Thalassomyces* spp. (Ellobiopsidae)(Figure 19). The gonomeres produce the flagellated spores which are presumed to be the infective stage of the parasite (Kane 1964, Galt and Whisler 1970, Mauchline 1980).

Horizontal Tow - for a horizontal tow the net is deployed rapidly until it reaches the desired depth; it is kept at that depth for the required length of time (30 minutes in this study), and is then brought back on board the ship.

Hyperbenthic - living in association with the bottom of the ocean, but not on or in the benthos. A hyperbenthic mysid may swim close to the bottom and snatch food particles from there but it does not rest on the sediment (Fössa 1986).

Isaacs-Kidd Midwater Trawl (IKMT) - a large, tapering net the mouth of which is kept open by a spreader bar and a depressor (Figure 6).

Iteroparous - producing many broods of offspring in a lifetime.

K-selection - natural selection which operates when resources are limited and the population of an organism is density dependent and is close to the carrying capacity of the environment (Elseth and Baumgardner 1981). This type of selection favours the genotypes of individuals which reproduce at a later age and larger body size (Emmel 1976).

Lamellae - thin-walled concave plates fringed with short strong setae that interlock ventrally to form a closed chamber, the brood pouch, below the thorax of a mature female mysid (Mauchline 1980). These plates are present on the second to eighth pair of thoracic legs of *Boreomysis nobilis*. The lamellae are also referred to as oöstegites.

Liner - a fine mesh net which is attached to the inside of the IKMT. It catches smaller organisms than would be caught by the larger mesh of an unlined IKMT (Figure 6).

Marsupium - see brood pouch.

Mesopelagic - organisms living at depths of 300 to 1500 m (Mauchline 1980) neither in association with the ocean floor, nor with the surface.

Oblique Tow - for an oblique tow the net is deployed rapidly until it reaches the desired depth. It is then immediately retrieved at a steady speed.

Oöstegites - see lamellae

Ovigerous Female - a mature female with a brood pouch containing larvae.

Rostrum - the anterior extension of the carapace above the eyes of a mysid. The rostrum of *B. nobilis* is long and pointed (Figure 1).

r-selection - natural selection which is not limited by resources; the rate of change in the size of a r-selected population is density-independent. This type of selection favours the genotypes which provide the highest rate of natural increase (Emmel 1976) and is a feature of opportunistic species which exploit new environmental situations as they appear (Elseth and Baumgardner 1981).

Semelparous - producing one brood of offspring in a lifetime.

Spiniform - pointed, like a spine.

Station - a single deployment of a net. Each time a net is deployed the tow is assigned a specific four digit station number, e.g. station 1902, which identifies the sample and the tow and distinguishes it from all other tows.

Telson - the last body segment in which the anus is not terminal (Schram 1986) (Figure 1).

Trophomere - the reproductive organs of the parasite *Thalassomyces* spp. (Ellobiopsidae). These projections branch out from the primary stalk of the parasite above the carapace of the host mysid (Figure 19).

Results

4.1 Morphology

Boreomysis nobilis (30,504 specimens) was collected at locations around the west and northeast coasts of Newfoundland (Table 1). An additional 770 *B. nobilis* were collected from Fortune Bay (Table 4) and were examined for parasites, brood and egg size. The total length could be measured for 29,997 of the specimens from the northeast coast and it ranged from 6.4 mm (juvenile, station 1902, Trinity Bay) to 49.2 mm (mature male, station 2023, Bonne Bay). The largest male was 10.8 mm smaller than the type specimen, also a mature male. The pleopods of the mature males were large and well-developed (Figure 1), unlike those of the females (Figure 15) and juveniles. The brood pouches of the females consisted of seven pairs of overlapping lamellae. Most *B. nobilis* that were caught for this study were bright orange and white in colour, although some specimens caught in White Bay were completely white. All specimens possessed a long pointed rostrum. The rostral plate of all the specimens examined was a single structure and did not consist of the two spiniform processes described by Brunel (1960).

4.2 Geographic Distribution

A total of 105 stations were sampled during four cruises: Dawson 86-026 (August

1986), Templeman-54 (November 1986), Baffin 87-016 (May 1987) and Dawson 87-030 (August 1987), with *Boreomysis nobilis* being taken at 67 stations (Tables 1 and 2). They were caught in Bonne Bay, Trinity Bay, White Bay, Bay of Exploits, Hall Bay, Green Bay, Badger Bay, New Bay and inner Bonavista Bay (Figures 3 to 5). *Boreomysis nobilis* were never caught in Conception Bay, at St. Barbe Island, outer Notre Dame Bay, outer Bonavista Bay, Newman Sound or at the mouth of the Bay of Islands (Figures 3 to 5).

Boreomysis nobilis were captured in water ranging in temperature from -1.3 to 2.2°C (mean temperature = -0.3 ± 0.1°C) and salinity from 32.4 to 34.0 ppt (mean salinity = 33.4 ± 0.4 ppt)(Table 1). These parameters approximate those at stations where *B. nobilis* were not caught (temperatures -1.3 to 2.8°C, salinities 31.4 to 33.7 ppt)(Table 2). The bottom depths of stations where *B. nobilis* were caught ranged from 229 m to 635 m, and for those stations at which the mysid was not caught, the depths varied from 211 m to 492 m (Tables 1 and 2).

Catch rates of *B. nobilis* were calculated for all stations (Table 5). At stations where the mysid was caught, catch rates were variable, ranging from 0.01 mysids per minute per m^2 (Station 1834, Bay of Exploits) to 44.6 mysids per minute per m^2 (Station 2024, Bonne Bay); the average catch rate was 6 ± 8 mysids per minute per m^2. In bays in which *B. nobilis* was found, the mysid was captured in the deepest areas of the bays. In all cases the water at the mouths of these bays was shallower than the areas in which the mysid was netted (Table 6). It was found in all of the

smaller bays off Notre Dame Bay that were sampled (Green, Hall, Badger and New Bays, and the Bay of Exploits); outside these bays in the middle of Notre Dame Bay (stations 1813-1817) only a single *B. nobilis* was taken. None were netted further out in the bay (stations 1760-1762). A similar pattern is exhibited in Bonavista Bay (stations 1836-1841). The mysid was not taken at the mouth of the Bay of Islands, nor was it found in the vicinity of St. Barbe Island between White and Notre Dame Bays. It was caught near the mouth and in the centre of White Bay but was not caught at the head of the bay (Figure 4). *Boreomysis nobilis* was also not found at the head of the Bay of Exploits (station 1835) and Bonavista Bay (Newman Sound, Stations 1763-1765), although it was found in the deep East Arm of Bonne Bay.

4.3 Nets

The length distributions of the samples of *Boreomysis nobilis* differed depending on the type of nets used. The bongo nets tended to catch more small *B. nobilis* (Figure 7, Table 7), and fewer large individuals than did the ten foot and six foot IKMT nets; thus, the length distribution of *B. nobilis* caught by the bongo nets tended to be skewed towards the smaller mysids, whilst that of *B. nobilis* caught by the IKMT nets tended to be skewed towards larger mysids. Significant differences were found in the mean lengths caught by each of the three nets (ANOVA, $F = 1654.04$, $p < 0.001$). The catches of the three nets were then compared and all nets were found

to be significantly different from each other ($p<0.05$, Scheffe's Multiple Contrast Test: Zar 1984). No comparison was made between the length distributions of the mysids caught by the two IKMT nets since these nets were never used on the same cruise or at the same time of the year. However, the length distributions of *B. nobilis* caught by the bongo nets and each of the IKMT nets were compared since the bongo nets were used on the same cruises as both types of IKMT nets. The mean length of *B. nobilis* caught by the bongo nets was 24.2 mm; the two IKMT nets tended to catch larger individuals than the bongos (mean length caught by ten foot IKMT = 30.8 mm, by six foot IKMT = 30.1 mm).

The frequency of males, females and juveniles caught by the three different nets were compared (Figure 8) and significant differences were found among the frequencies of the sexes caught by the three nets (Chi-squared test, $X^2=1710.44$, $p<0.001$). The bongo nets caught more juveniles, which are the smallest stages, whilst the IKMT nets caught more males, which are the largest (Figure 8). There was not much difference between the proportions of females caught by the different nets since females are of intermediate size and would be sampled similarly by all nets.

Since the samples from Templeman-54 were not originally intended for this study, the method in which they were taken differed from that used on the first cruise, Dawson 86-026. On the Templeman-54 cruise, all tows using the bongo nets were oblique. In the two later cruises (Baffin 87-016 and Dawson 87-030), both horizontal

and oblique tows were conducted at similar locations with the bongo nets so that they could be compared to see if there were any differences in the catch of *B. nobilis*. There were differences were between the length distributions of *B. nobilis* caught in May and August 1987 by the different methods of towing, with the mean length of mysids caught by oblique tows being larger (25.1 mm) than the mean length of mysids caught by horizontal tows (24.0 mm)(Table 8). Such a small difference (1.1 mm) in mean length is unlikely to be biologically significant. There was not much difference between the length frequency histograms for oblique and horizontal bongo tows (Figure 9). The horizontal bongo tows did catch more small juveniles which resulted in a smaller mean length of *B. nobilis*, but the modes in the length frequency distributions were similar for both horizontal and oblique tows (34 mm to 36 mm)

4.4 Vertical Distribution

The percentage of the wet weight of the total samples that *B. nobilis* comprised was found to be significantly different between depths for all nets at all stations (ANOVA, $F=4.70$, $p<0.001$)(Table 9). *Boreomysis nobilis* comprised up to 48% (mean = 21 ± 9%) of the total wet weight of samples collected between 0 and 50 m above the bottom, indicating that it is a major component of the deep water zooplankton.

No significant differences were found among the catch rates (mysids per minute

per m^2) of juveniles, males and females at different distances above the bottom (ANOVA, $F=0.25$, $p>0.05$). The highest catch rates for all three groups were in the first 150 m above the bottom and there was a trend of decreasing catch rate with increasing distance above the bottom (Figure 10). Similarly, no significant differences were found among the catch rates of juveniles, immature and mature stages at different distances above the bottom (ANOVA, $F=0.08$, $p>0.05$), but again the highest catch rates for these three groups were in the deepest water, less than 150 m above the bottom, and these catch rates decreased as the distance above the bottom increased (Figure 11).

No significant relationship was found between the time of day at which a tow was taken (day versus night) and the catch rates of *B. nobilis* at different depths above the bottom (ANOVA, $F=1.52$, $p>0.05$ for all stations from Templeman-54, Dawson 87-030 and Baffin 87-030; $F=1.57$, $p>0.05$ for horizontal bongo tows from Dawson 87-030 and Baffin 87-016).

4.5 Population Characteristics

An examination of the length frequency distributions of the six different life history stages indicated that length depended on stage (Chi-squared test, $X^2=3446.5$, $p<0.001$). The minimum total length was recorded from a juvenile and was 6.4 mm

(Station 1902, Trinity Bay); the largest male was 49.2 mm (Station 2023, Bonne Bay) and the largest female was 42.2 mm (Station 1916, White Bay). The length distributions of the different life history stages caught in White Bay at three different times of the year were compared. White Bay was chosen since the samples were taken using the same equipment (bongos) at approximately the same depths and locations (Table 10). The smallest juvenile in the White Bay sample was caught in August 1987 and was 7.8 mm in length (Station 2020); the largest stage 3 larva recorded from White Bay was 7.6 mm (Station 1806). Thus, the bongo nets did catch a few of the smallest juvenile stages. However, only 17 juveniles of lengths less than 10 mm were caught in all the White Bay samples, and such small numbers did not show up on the length-frequency histograms (Figure 12); therefore, the bongo nets did not sample the smallest juveniles effectively. It is possible that the smallest juveniles stay close to the bottom and were therefore not caught by a net designed for sampling pelagic organisms. This type of behaviour has been observed in other mysid species (e.g. Fössa 1985).

The length distributions of all six stages combined were bimodal on all three sampling dates (Figure 12). The largest number of small juveniles was caught in August 1987; the mode for the juveniles was about 16 mm. In November 1986 and May 1987 the mode for the juveniles was about 20 mm. The second peak of large immature and mature mysids did not vary in mean length from season to season. There was also no seasonal variation in the minimum size of males and females

reaching sexual maturity (24.9 mm for males, 26.8 mm for females) or in the ratio of males to females in the population (Table 11).

The differences in the numbers of life history stages caught at three different times of the year were also examined for White Bay stations (Figure 13). The percentage of mature males (stage 3) increased from 20.3% in November, 1986 to 27.9% in April, 1987, and decreased by August,1987, to 10.2%. The immature females (stage 4) were most common (33.5%) in April 1987 and comprised 24.6% of the sample in November and 20.3% in August. Ovigerous and spent females (stages 5 and 6) were never numerous, but the largest percentage of ovigerous females was found in November, 1986 (5.8%). Juveniles were abundant (36.2%) in November, 1986, but declined to 17.1% by April 1987 and reached a peak of 45.8% in August.

4.6 Reproduction

A total of 1032 ovigerous females was examined from the Dawson 86-026, Templeman-54, Baffin 87-016 and Dawson 87-030 cruises. Samples of ovigerous females caught with the ten foot IKMT contained a higher percentage (56.9%) of damaged marsupia than did the bongo net samples (40.5%); this difference was significant (Chi-squared test, $X^2=27.13$, $p<0.001$). Mysids caught using the six foot

IKMT net were not used in this analysis since the sample size was so small (n=16).

The average number of larvae in a full marsupium was 23 ± 4 for stage 1 (n=66), 22 ± 4 for stage 2 (n=314) and 17 ± 5 (n=81) for stage 3 larvae; thus the number of larvae in the brood pouch decreased as the larvae developed from stage 2 to stage 3. According to the method of Mauchline (1973), this indicates a 26% mortality rate during the development of the larvae of *B. nobilis* from stage 1 to stage 3. The mortality rate was also calculated for samples from each cruise; it was 21.6% in August 1986, 46.0% in November 1986, 34.8% in May 1987 and 13.5% in August 1987. If *B. nobilis* breeds throughout the year, then the ratio of the mean percentages of ovigerous females carrying the three different stages should reflect the length of time that larvae take to pass through each stage (Mauchline 1973). The ratio of the percent of females carrying the three larval stages was 14% stage 1 : 68% stage 2 : 18% stage 3.

A comparison was made between the number of larvae (fecundity) found in the marsupia of ovigerous females at three different times of the year (November 1986, April 1987, August 1987). Since the size of the broods depends on the stage of development of the larvae, only brood pouches containing larvae of the same stage of development were compared. For all three stages a significant difference was found in the number of larvae from the three different times of the year (ANOVA, stage 1 $F=3.53$, $p<0.03$; stage 2 $F=7.48$, $p<0.001$; stage 3 $F=4.18$, $p<0.02$). However, since the sample size of ovigerous females from the November 1986 cruise

(Templeman-54) was so small (n=14), little can be inferred from it. The mean, minimum and maximum number of larvae for each stage are shown in Table 12. The mean, intact brood size for all ovigerous females caught in August, 1987, is slightly larger than that of those caught in the spring. However, the range of brood sizes is similar for all three times of the year.

No significant difference was found in the frequency of ovigerous females carrying the three different larval stages at different times of the year (Chi-squared test, $X^2=6.07$, $p>0.05$)(Table 12). The spring and summer samples had similar percentages of the different larval stages, with stage two larvae being most common. In the small (n=14) November sample, stage one larvae were most numerous.

The relationship between brood size and the cube of the total body length (an estimate of volume: Mauchline 1973) of the ovigerous females is shown in Figure 14. Only broods containing stage 1 larvae were examined so that the results could be compared to the findings of Mauchline (1973, 1980). A significant positive relationship between log brood size and log total body length cubed was found ($r=0.61$, $p<0.001$), indicating that larger *B. nobilis* have larger broods. The regression lines calculated by Mauchline (1980) for coastal and epipelagic mysids and for meso- and bathypelagic mysids are also included on Figure 14. The point plotted for *B. nobilis* is closer to the line calculated by Mauchline (1980) for meso- and bathypelagic species than to that calculated from coastal and epipelagic species of mysids.

Stage one larvae are spherical, and thus their diameter and volume can be calculated. The volume of the brood is then calculated by multiplying the mean volume of the larvae by the number of larvae in a brood (Mauchline 1980). The length, brood size and diameter of stage 1 larvae ("eggs") were measured for ovigerous females with intact marsupia from the Templeman-54, Baffin 87-016 and Dawson 87-030 cruises (Table 13). The brood size, and therefore pouch volume, varied greatly among the sixty ovigerous females with intact brood pouches, whereas the diameter of stage 1 larvae was more constant. The relationship between the average egg diameter (1.6 ± 0.1 mm) and average length (35.1 ± 1.6 mm) cubed for ovigerous *B. nobilis* is closer to the regression line calculated by Mauchline (1980) for meso- and bathypelagic mysids than to the line calculated for coastal and epipelagic mysids. The average brood volume versus length cubed for *B. nobilis* is above the regression line calculated by Mauchline (1980) for 157 species of mysids.

The stage 2 and stage 3 larvae in the marsupia of ovigerous *B. nobilis* tended to be oriented in a regular fashion. Although the heads of the majority of the larvae were pointing posteriorly (according to the convention of Mauchline (1980)), larvae proximal to the female's thorax tended to point in an anterior direction (Figure 15). This was the case for 81% of the full brood pouches containing stage 2 larvae and 95% of those containing stage 3 larvae. In the remaining 19% of full marsupia containing stage 2 larvae, between 1 and 6 larvae were found to be facing anteriorly in the centre of the brood pouch. Between 2 and 4 stage 3 larvae were found to be

facing forward in the 5% of brood pouches that contained larvae that were not regularly oriented.

Thirteen out of 461 brood pouches contained larvae at more than one stage of development (Table 14); the presence of more than one larval stage is often cited as evidence of adoption (Mauchline 1980). Four of the 13 brood pouches contained large numbers of stage 1 larvae and a smaller number of early stage 2 larvae. Seven marsupia contained a small number of stage 1 larvae and a larger number of stage 2 larvae; the remaining 2 brood pouches contained a larger number of stage 2 larvae and a single stage 3 larva.

4.7 Parasites

The ellobiopsid parasite *Thalassomyces boschmai* (Nouvel 1954) is recorded from *Boreomysis nobilis* for the first time. *Thalassomyces boschmai*, found on the carapaces of the mysids (Figure 16), was identified using the keys of Kane (1964) and Wing (1975). The primary stalk of the parasite penetrated the carapace under which it became more bulbous in shape, forming a compact organ of fixation (Figure 17). Above the carapace the primary stalk of the parasite branched into many trophomeres with clearly distinguishable distal gonomeres (Figures 17, 18 and 19). The mature gonomeres were ellipsoidal, and exhibited the polygonal faceting or "demi-spheres" described for *T. boschmai* by Nouvel and Hoenigman (1955) and for

T. marsupii Kane 1964 by Galt and Whisler (1970) (Figures 18 and 19).

In total, 31,274 specimens of *B. nobilis* from six different cruises (Fortune Bay cruises, Dawson 86-026, Templeman-54, Baffin 87-016 and Dawson 87-030) were examined for the presence of parasites. *Thalassomyces boschmai* was found on 35 specimens of *B. nobilis*, an infection rate of 0.1% (Table 15). No *T. boschmai* were found on *B. nobilis* from Fortune Bay (May 1982, June 1983) or from the Templeman-54 cruise in November 1986. *Thalassomyces boschmai* were found on 19 *B. nobilis* from Trinity Bay in August 1986; at station 1766, 11.2% of the *B. nobilis* caught were infected with *T. boschmai,* and at station 1767, 0.7% were infected. In April, 1987, infected animals were found in samples from four stations in Trinity Bay (1902, 1904, 1905 and 1906) and from the Bay of Exploits (1909). The proportion of *B. nobilis* infected by the parasite was 0.2% for Station 1902, 1.1% for 1904, 0.3% for 1905, 1.2% for Station 1906 and 0.3% for Station 1909. In August, 1987, *B. nobilis* from Trinity Bay were again found to be infected with *T. boschmai*; the prevalence was 0.19% at Station 2008 and 0.39% at Station 2009. No *B. nobilis* bearing *T. boschmai* were found in any of the other bays that were sampled.

Only juvenile and immature males and females were infected with *T. boschmai.* No mature males and females were found with this parasite. In all cases the total lengths of the infected mysids fell within the normal range for their stage of development (Table 15). No *B. nobilis* were infected with more than one specimen of *T. boschmai.* One specimen of *T. boschmai* was found loose in the sample

collected from station 1766. The parasite consisted of only the trophomeres and primary stalk and had obviously been broken off.

Discussion

5.1 Morphology

Sars (1879) described the type specimen of *Boreomysis nobilis* as being a rich red colour in parts. Many of the specimens caught for this study were orange and white, although a few individuals from White Bay were completely white. All specimens collected for this study conformed with Sars' (1879) description of the species. There was no evidence of a rostrum that was composed of two closely appressed spiniform processes as indicated by Brunel (1960). The largest *B. nobilis* caught in this study was 49.2 mm; this is considerably smaller than the 60 mm length of the type specimen (Sars 1879). The length of a mysid may be measured in several ways (Mauchline 1980), and since Sars (1879) did not indicate how he measured the type specimen, it is not certain exactly how much bigger it is than the specimens collected for this study.

5.2 Geographic Distribution

Boreomysis nobilis is reported from nine new locations around the island of Newfoundland. In this study, the variation in the catch rates of *B. nobilis* indicated that it was most common in the deep fjords around Newfoundland and was not common outside these fjords. This finding is in agreement with Richard (1987), who

reported *B. nobilis* from Fortune Bay but not from the Hermitage, St. Pierre and Laurentian Channels; with Wright (1972), who found *B. nobilis* in Bonne Bay but not in the Gulf of St. Lawrence; and with Judkins and Wright (1974), who found *B. nobilis* in the Saguenay Fjord but not in the St. Lawrence Estuary and the Gulf of St. Lawrence. The data presented here support the conclusion of Wright (1972), that *B. nobilis* is a cold water species restricted in southeastern Canadian waters to coastal fjords.

Prior to my study, *B. nobilis* had been found south of the Arctic Circle only in waters colder than 0°C (Dunbar 1940, Tattersall 1939, Wright 1972, Judkins and Wright 1974); in this study *B. nobilis* was found in waters up to 2.2°C and in a wide range of salinities (31.4 to 33.7 ppt). *Boreomysis nobilis* was found in the deep channels in the middle of White bay and the Bay of Exploits, but not at the heads of these bays, even though the depths, temperatures and salinities there were within the range in which the mysid had been found elsewhere (Tables 1 and 2, Figure 4). The depth of the water at the mouths of the bays was consistently less than the depths of the stations at which *B. nobilis* was captured (Table 6). If shallower water acts as a partial barrier to the mysid, it would explain why *B. nobilis* was common inside the bays, but was rarely encountered outside these areas.

Boreomysis nobilis was not found in Newman Sound and Conception Bay even though the water depths at the stations sampled were greater than 200 m and the temperature and salinity ranges were within the range inhabited by *B. nobilis*.

Therefore, some factor(s) other than water temperature and salinity must influence local distribution. A major influence on all the bays along the northeast coast is the Labrador Current (Davis 1986). Conception Bay and Newman Sound both receive an influx of Labrador Current water. However, both bays are shallower overall and have shallower sills (<200 m) than the bays on the northeast coast in which *B. nobilis* were found. *Boreomysis nobilis* was always caught at depths greater than 200 m and at depths greater than the sill depths at the mouths of the fjords (Table 6). An examination of the 200 m contour line along the northeast coast (Figure 20) indicates a trough of deep water in the centre of all the bays in which *B. nobilis* was found. There are pockets of deep water (>200 m) in Conception Bay and Newman Sound but these are not contiguous with the open ocean. It is therefore possible that the shallow sills at the mouths of Conception Bay and Newman Sound and the absence of large areas of deep water in these bays prevents the establishment of populations of *B. nobilis*.

Wright (1972) suggested that *B. nobilis* is a glacial relict in the coastal fjords of southeastern Canadian waters. Drainville (1970) also concluded that the arctic and subarctic species of the Saguenay Fjord were glacial relicts. Judkins and Wright (1974) questioned this glacial relict hypothesis, suggesting that there had been more recent faunal exchanges between the Arctic and the Saguenay Fjord. It is unlikely that *B. nobilis* is a glacial relict in Newfoundland waters since there is a constant influx of Arctic water into all the bays sampled in this study. The Labrador Current

carries cold, low salinity water from the Labrador Sea, down the northeast coast of Newfoundland to the northern edge of the Grand Banks (Talley and McCartney 1982, Petrie and Anderson 1983). At this northern edge the Labrador Current splits into three parts, one of which flows around the Avalon Peninsula of Newfoundland, along the south coast of the island and then into the Gulf of St. Lawrence and northeast along the Newfoundland west coast (Petrie and Anderson 1983). Thus, *B. nobilis* could be transported south in the Labrador Current to the bays around the Newfoundland coast. Populations of the mysid would be established in bays with suitable physical parameters. *Boreomysis nobilis* was caught at depths which were below the sill depths at the mouths of the fjords (Table 6), which is similar to the distribution of *B. megalops* in Masfjorden, Norway (Kaartvedt 1989). In Masfjorden there was extensive water exchange above the sill depth, but the presence of the sill prevented large scale advection of the deep living mysid populations (Kaartvedt 1989). In the Newfoundland fjords, *B. nobilis* were probably swept into the bays by the Labrador Current. The populations then became established below the sill depth where advective currents would be reduced. Mysids that moved up into the waters above the sill depth, would be more likely to be swept out of the bay where conditions would be unsuitable for populations to be established. As a result of the constant influx of Labrador Current water, it is unlikely that *B. nobilis* populations are glacial relicts in Newfoundland waters; instead, they are disjunct populations which were likely established by individuals swept south in the Labrador Current.

These populations would be augmented by new individuals brought down from the Arctic by the Labrador Current.

5.3 Nets

The type of net used in this study determined the type of data collected, since factors such as net avoidance and escape likely varied with the net used. Bongo nets caught more small juvenile and immature stages than the six and ten foot IKMT nets. Nets like the bongos, with a small mesh size (330 μm), collect the small, young stages more efficiently, but larger stages are likely able to avoid the net as it passes through the water. The larger the mouth of the net, the more difficult it is for zooplankton to escape its path (Fleminger and Clutter 1965, Raymont 1983). The IKMT nets have much larger mouth openings than the bongo nets and thus large individuals would be less able to swim out of the path of these nets. However, the smaller juvenile stages were able to pass through the larger (10 mm) mesh of the liner of the IKMT nets. Each type of net samples a plankton population differently and provides a different "view" of that population, making it difficult to compare collections made with different sampling devices (Angel 1976). None of the nets used gave a complete picture of the population of *B. nobilis*, but each gave some information that the others did not. Thus, although the catches of these nets cannot be directly compared, they can be considered to be complementary.

Differences in the way in which the bongo nets were fished did not appear to influence the samples, since the length distributions of *B. nobilis* caught by horizontal and oblique tows exhibited a similar modality. The major difference was in the numbers of *B. nobilis* caught, but when catch rates, instead of total numbers, were examined, oblique tows caught *B. nobilis* at about the same rate as did horizontal tows. Therefore the type of sampling device used had more influence on the data collected than did the method by which the net was recovered.

5.4 Vertical Distribution and Zonation

Most species of mysid are functionally tied to the ocean bottom by living in or on the sediment or swimming close to it (Fössa 1985, Kaartvedt 1985). Some species of mysid that are considered to be meso- or bathypelagic likely are not truly pelagic, but are restricted to the hyperbenthos, the water layer adjacent to the sea bottom (Mauchline 1980). At the stations sampled in this study, *B. nobilis* was most common in the first 150 m above the sea bottom; indeed, the largest catch rate from the Baffin 87-016 cruise was recorded from station 1916 in White Bay, where the ten foot IKMT hit the bottom. *Boreomysis nobilis* was a major component of the zooplankton in the deep water, comprising up to 48% of the wet weight of total samples of zooplankton collected within 50 m of the bottom. Like *Boreomysis megalops* and *Hemimysis abyssicola* (Fössa 1986), *B. nobilis* probably swims close to the bottom,

perhaps feeding from the bottom, but not resting on it. Therefore, *B. nobilis* is a hyperbenthic mysid which is predominant in the water close to the sea bottom. However, it is also found in smaller numbers up to 500 m above the bottom. This observation is in agreement with Wright (1972), who concluded that *B. nobilis* in Bonne Bay is a bottom planktonic form which is capable of moving over fairly large vertical distances in the water column.

Differences in the vertical zonation of the life history stages have been observed for other mysid species (e.g. Clutter 1967, Fössa 1985). In this study, no differences were found in the vertical zonation of the life history stages of *B. nobilis* although all stages are most common closest to the bottom (Figures 10 and 11).

The vertical distributions of many species of hyperbenthic mysids vary depending on the time of day (Mauchline 1980, Attramadal *et al.* 1985, Kaartvedt 1985). However, like *Mysis mixta* and *Mesopodopsis slabberi* (Hesthagen 1973), the data collected for *B. nobilis* showed no evidence of diel vertical migration. Variation has been found in the vertical distribution of life history stages of some species of mysids depending on whether collections were made during the day or night (e.g. *Boreomysis megalops*: Kaartvedt 1985). *Boreomysis nobilis*, however, does not show any evidence of diel changes in vertical zonation.

5.5 Population Characteristics

Boreomysis nobilis differs from many other species of mysid in several characteristics of its population structure. Female mysids generally grow to a larger size than males (Mauchline 1980); this is not the case with *B. nobilis*. In all of the samples collected at three different times of the year, the largest *B. nobilis* caught were mature males. Also, unlike many other mysid species (e.g. *Teganomysis macropsis*: Greenwood *et al.* 1985), there was no seasonal variation in the size at sexual maturity for males and females, although males do become sexually mature at a smaller size than females (Table 11). Further, no seasonal variation was noted in the sex ratio, which only varied from 1:1 to 1:1.3 (Table 11). In many other species of mysid, females outnumber males (Mauchline 1980), although ratios of 1:1 are not unknown (Brattegard 1973, 1974). The constant ratio of males to females in populations of *B. nobilis* is evidence for continuous breeding, since species which have seasonal breeding cycles often exhibit periods when few or no males are sexually mature (Mauchline 1980).

The length frequency histograms of *B. nobilis* collected by bongo nets in White Bay were bimodal at all three times of the year that samples were collected (Figure 12); this is in agreement with the length frequencies of *B. nobilis* collected in Bonne Bay in July and September 1970 (Wright 1972). The length frequencies differed from those of *B. nobilis* collected in July and August in Ata Sound, Greenland where the

population was not clearly bimodal and where juveniles predominated (Dunbar 1940). The bimodality of the length-frequency histograms in this study indicated two separate cohorts. As suggested by Wright (1972), these two cohorts probably represent two separate year classes as opposed to two separate broods produced in the same year. *Boreomysis nobilis*, like *Mysis litoralis* from the Arctic Ocean and *M. oculata* from Spitsbergen (Geiger 1969, Weslawski 1989), probably has a two year life cycle, becoming sexually mature and breeding in its second year of life.

The large size of mature *B. nobilis* supports this hypothesis as do the histograms of the percent frequency of the different life history stages by season (Figure 13). If a mysid has a one year life cycle, with one brood in that year, there will be a period when there are large numbers of adults and juveniles and small numbers of immature individuals. Once the juveniles are released, the adults die; the juveniles then develop into immature individuals. At this point there will be a large number of immature mysids, few juveniles and no adults. In a two year life cycle there will always be a large number of immatures, even though the numbers of juveniles and adults will fluctuate. A slight increase in the number of immatures would occur when the large number of juveniles produced begins to mature. These patterns would be obscured by continuous breeding at a constant rate throughout the year, but should still be evident if there were a peak in reproductive activity at some point in the year. The percent frequency histograms for *B. nobilis* (Figure 13) show that there are substantial numbers of immature individuals in the population at all times, indicating

that this mysid has a two year life cycle. Mauchline (1980) speculated that *B. nobilis* is probably semelparous like *Gnathophausia ingens* (Childress and Price 1978), because of its longer life cycle. *Boreomysis nobilis* would be unlikely to be iteroparous if it carries its brood for as long as other species of cold water mysid (e.g. 120 days for *Mysis oculata* from Spitsbergen: Weslawski 1989, up to 270 days for *Mysis relicta* in Arctic lakes: Lasenby and Langford 1972).

Discrete shifting of length-frequency peaks over time indicates the growth and maturation of the individuals in a population. Thus seasonal peaks in reproduction can be determined from peaks in the frequencies of the different life history stages. This method has been used extensively for many different species of mysid (e.g. *Heteromysis formosa*: Allen 1982, *Mysis stenolepis*: Amaratunga and Corey 1975). Discrete shifting of size-frequency peaks may not always be easily observed, however, since other factors such as age-specific mortality and the presence of extended or continuous breeding may complicate the picture (Astthorsson and Ralph 1984). To get a clear picture of the dynamics of a population of mysids, sampling should be more frequent than in this study (e.g. weekly or monthly as in Mauchline 1965, 1967). In the absence of such data, some generalizations can still be made. In the length-frequency histograms of Figure 12 there was a change in the mode at the lower end of the length scale from November to May to August; the modal range in November was 16 to 20 mm and consisted mostly of juveniles. In May the percent of juveniles in the samples was at its lowest but by August juveniles were once again a large

component of the samples. The bimodality of the length-frequencies from season to season, and the presence of all life history stages at all times of the year, indicates continuous recruitment of juveniles into the population. However, the variation in frequency of the different life history stages and in the modal length of juveniles indicates that there is some degree of seasonality involved in reproduction.

The smallest juvenile captured in the White Bay samples was 7.8 mm, and the largest stage 3 larva measured was 7.6 mm; this suggests that the juvenile mysids emerged from the marsupia of the females at a length of about 7.5 to 8 mm. The smallest juveniles caught in large enough numbers to show up in the length-frequency histograms were captured in August 1987; the mode for these juveniles was 16 mm. If juvenile *B. nobilis* have a growth rate similar to other species of cold-water mysids (e.g. 0.05 to 0.08 mm/day for *Mysis mixta* from the Baltic: Rudstam and Hansson 1990; 0.08-0.09 mm/day at 1-4°C for *M. oculata* from Spitsbergen: Weslawski 1989; 0.05 mm/day at 1-4°C and 0.08 mm/day at 9-12°C for *M. oculata* from Iceland: Astthorsson 1990) then it would take about 75 to 100 days for *B. nobilis* to grow from 8 mm to the peak of 16 mm in August. This means that the juveniles were released in May. Many species of cold-water mysids with two-year life cycles release their young in the spring like *B. nobilis* (Lasenby and Langford 1972, Weslawski 1989, Rudstam and Hansson 1990). This spring release coincides with the onset of milder climatic conditions and an increase in the availability of food. In Newfoundland inshore waters the spring plankton bloom occurs in April and May (Pomeroy and

Deibel 1986). Thus at this time food is most abundant for juvenile *B. nobilis*. The peak of very small juvenile *B. nobilis* (8 mm) did not show up in the May, 1987 length-frequency histogram because the smallest juveniles were not effectively sampled by the bongo nets. The mode in May, 1987, was 24 mm and the mysids of this length were mostly immature, not juveniles. The length-frequency mode for juveniles caught in November was 20 mm. A daily growth rate of between 0.05 and 0.08 mm per day is consistent with the shift in the mode of the length distribution of juveniles from August to November. Over the winter the juveniles grew and developed into immature males and females. By the summer these mysids were mature and breeding occurred.

The percent frequency of the life history stages (Figure 13) supports the hypothesis of summer breeding and the release of juveniles in the spring. As indicated by the length-frequency histograms, the smallest juveniles were released in May. If these small juveniles had been caught with the bongo nets, then the percentage of juveniles in the May, 1987, samples would have been higher. These juveniles grew between May and August, and thus were caught in August, 1987, which was when the largest percentage of juveniles (45.8%) was found. These juveniles developed over the winter into immature males and females so that by May the percentage of immature individuals in the population was at its highest (47.5%). Male *B. nobilis* become sexually mature at a shorter length (24.9 mm) than did females (26.8 mm); thus the male mysids matured sooner than the females, as is

shown by the increase in the percentage of mature males (27.9%) and the large numbers of immature females (33.5%) in May. Breeding occurred between May and August when the females matured, and then the male mysids began to die off whilst the numbers of ovigerous females increased (Figure 13). Mortality of males after reproduction is common in other species (e.g. *Mysis stenolepis*: Amaratunga and Corey 1975). In November, the percentage of ovigerous females was at its peak (5.8%). The ovigerous females then overwintered, releasing their young in the spring when food was plentiful. The lowest percentage of ovigerous females was found in the spring (1.4%), indicating that the females had released their larvae. The long incubation period from late summer to the following spring is within the range reported for other cold water species of mysids (e.g. up to 270 days at 0.5 to 3°C for *Mysis relicta* in an arctic lake: Lasenby and Langford 1972). Since the duration of development in the marsupium is also related to temperature (Mauchline 1980), it would be expected that a cold-water mysid like *B. nobilis* would exhibit a long incubation period. *Boreomysis nobilis* has a large egg (1.4 to 1.8 mm) in comparison to many other northern mysids (e.g. 0.7 to 1.0 mm for *Mysis oculata*: Weslawski 1989, Astthorsson 1990; 0.8 mm for *B. arctica*: Jepsen 1965; 0.6 to 0.64 mm for *M. mixta*: Mauchline 1973). There is a positive correlation between egg size and development time for invertebrate eggs (McLaren 1966, Steele and Steele 1975, Steele 1977, Wittmann 1984, Lonsdale and Levinton 1985). A mysid, like *B. nobilis*, which produces large eggs would be expected to have a long development period. Thus an

incubation period of 200+ days for *B. nobilis* larvae is likely.

The life cycle of *B. nobilis* can be summarized as follows: breeding occurs in the population throughout the year, since all life history stages are present at all times, but there is an increase in reproductive activity between May and August. The juveniles are released in the spring and grow throughout the first year, developing into immature mysids by the following spring. The male mysids mature first and breeding occurs in the early summer when the immature females mature. The males die after breeding, but the ovigerous females live through the winter, releasing their young the following spring.

5.6 Reproduction

Since *Boreomysis nobilis*, like all mysids, carries its young in a marsupial pouch, it is possible to examine such factors as fecundity, egg and larval size, and many aspects of larval development. The ten foot IKMT net was a more destructive method of sampling ovigerous females than the bongo nets, since 56.9% of those caught by the IKMT had damaged marsupia compared to 40.5% in samples caught by bongo nets. Thus, in a study of the reproductive biology of *B. nobilis* the bongo nets are the better sampler.

The mortality rate for the larval development of *B. nobilis* was lowest in the August samples and highest in November. The overall mortality rate of 26%,

calculated using broods from all four cruises, is considerably higher than the 10% calculated for eight species of British mysids (Mauchline 1973) and the 11% calculated for *Leptomysis lingvura* (Wittmann 1981). In almost all cases the loss of larvae from the brood pouch can be assumed to result in death, since the larvae are not capable of much movement (Wittmann 1984). A small number of lost larvae may be adopted by other females but this appears to be a rare occurrence. As the larvae grow and mature, the brood volume increases and so the overlap of the marsupial plates which make up the brood pouch is reduced to increase the volume of the pouch. This stretching of the brood pouch may result in the loss of some larvae (Wittmann 1984).

The relative proportions of females carrying the different larval stages should reflect the length of time that the larvae take to pass through each stage (Mauchline 1973). If this is the case with *B. nobilis,* then the ratio of 0.14 (stage 1): 0.68 (stage 2): 0.18 (stage 3) indicates that stage 2 takes the longest amount of time, lasting four to five times longer than stages 1 and 3. The second larval stage of the related species *Boreomysis arctica* is also known to last the longest, although not as long in relation to the duration of the other two larval stages (Jepsen 1965). The duration of stage 1 and 3 larvae appears to be very similar; again this timing is similar to that for *B. arctica* (Jepsen 1965). Since *B. nobilis* does appear to exhibit a period of increased reproductive activity, the ratio calculated for the duration of larval development may not be entirely accurate; however, it does give some idea of the

relative durations of the different larval stages. In the Arctic, the duration of larval development is usually between 35% and 50% of the average generation time, considerably longer than the 15% to 30% of temperate and tropical mysids (Wittmann 1984). The larvae of cold water mysids like *B. arctica*, *Mysis relicta* and *Gnathophausia ingens*, are known to have development times of between 100 and 530 days (Mauchline 1980). It is likely that the larvae of *B. nobilis* also develop relatively slowly.

Many species of mysid are known to exhibit seasonal variation in brood size (e.g. *Praunus inermis:* Mauchline 1965 and *Schistomysis spiritus*: Mauchline 1967). However, for *B. nobilis* the ranges of brood sizes were similar for all three times of the year (Table 12). There was no seasonal variation in the proportion of ovigerous females carrying each of the three different larval stages. Most ovigerous females in May and August were carrying stage 2 larvae, which would be expected since the development of the second stage larvae is of the longest duration. The fall sample was too small (n=16) to allow any conclusions.

Larger individuals of *B. nobilis* carry a larger number of stage 1 larvae in their brood pouches (Figure 14). The relationship between brood size and body length for *B. nobilis* is closer to that reported for meso- and bathypelagic mysids than for epipelagic and coastal species by Mauchline (1980). Thus, even though it fits the definition of Mauchline (1972) for an epipelagic mysid, *B. nobilis* produces fewer larvae relative to its body volume than a typical epipelagic or coastal mysid. In terms

of the relationship between egg volume and length cubed, *B. nobilis* is again more similar to the meso- and bathypelagic species, producing a larger egg than a typical epipelagic or coastal species of the same size. Wittmann (1984) found that epipelagic cold water breeders conform with meso- and bathypelagic species and produce larger eggs relative to their body size than coastal and epipelagic warm water breeders. *Boreomysis nobilis* conforms to Wittmann's (1984) definition of a cold water breeder since it releases the majority of its young in the spring however, is semelparous, and has a life-cycle of two years. Thus the relationship between brood size, egg size and body volume for *B. nobilis* is like those of other cold-water breeders and conforms more closely with those calculated for meso- and bathypelagic mysids.

In producing a smaller number of large eggs relative to its body volume, *B. nobilis* is exhibiting a tendency towards a more K-selected life history strategy (Elseth and Baumgardner 1981, Emmel 1976) than the typical epipelagic and coastal mysids in Mauchline's (1980) analysis. K-selection would favour the slower development and later maturation and reproduction demonstrated by *B. nobilis* in comparison to many other epipelagic mysids which tend to have relatively short life spans of up to a year (Mauchline 1972). K-selection would also favour smaller numbers of large eggs with longer periods of larval development. Rather than producing a large number of small eggs, *B. nobilis* puts more energy into each of a small number of large eggs which will have a better chance on an individual basis of surviving to maturity. A more r-selected strategy, as evidenced by most epipelagic mysids, would be effective

for mysids that are widely distributed, less dependent on the sea bottom, and perhaps feed on plankton blooms and are therefore not resource-limited at the time of reproduction. A mysid such as *B. nobilis,* which shows a more restricted geographical distribution, is hyperbenthic, and feeds mostly on non-calanoid crustacea (Wright 1972), would be influenced more by the availability of resources. The production of a few hardy offspring in these circumstances would be more advantageous than the production of a large number of small offspring. Large eggs of fish and invertebrates usually produce large young (Thorson 1950, Marshall 1953, Mauchline 1972, Steele and Steele 1975). The survival of the young invertebrate larvae is often correlated with their size (Wittmann 1984). The production of fewer, but larger, eggs and therefore larger juveniles by *B. nobilis* means that the young juveniles can probably eat a greater range of food and can quickly adapt to an adult diet (Mauchline 1972). A larger juvenile would probably also have a greater swimming ability and thus would be more able to avoid predators (Mauchline 1972).

Boreomysis nobilis produces a larger brood volume in relation to its body volume than would be expected from the regression line calculated for all species of mysids by Mauchline (1980). This larger brood volume is directly related to the larger egg volume. The egg volume to body volume ratio is also larger than that predicted for meso- and bathypelagic mysids and epipelagic and coastal mysids (Figure 14). Egg volume is known to be latitude and temperature dependent for many species of invertebrates (e.g. Thorson 1950, Wittmann 1984, Toda *et al.* 1987) and fish (e.g.

Marshall 1953, Thresher 1988). Egg sizes of mysids increase with decreasing temperature or increasing latitude (Wittmann 1984). Since *B. nobilis* lives in relatively cold water, -1.3°C to 2.2°C, it would be expected to have large eggs relative to its body size. Although my data do not address the variation in egg size with latitude or temperature, these factors may affect egg volume, complicating the data and, in the case of temperature, resulting in a larger egg volume to body volume ratio than might be expected.

Unlike the generalization of Mauchline (1980), the stage 2 and 3 larvae in the marsupia of ovigerous *B. nobilis* were not all oriented with their heads facing posteriorly. They did tend to be oriented in a regular fashion, but the larvae closest to the thorax of the female were facing anteriorly (Figure 15). This regular orientation allowed a large number of larvae to be packed into a smaller volume. Some full brood pouches were found with more larvae facing anteriorly; this may be due to the destructive action of the nets on the marsupia, the movement of the brood lamellae by the female, or some limited movement by the larvae themselves. The brood lamellae of female mysids have been observed moving rhythmically presumably to irrigate the larvae, and some movement has been observed in stage 2 and 3 larvae of *Neomysis americana* and *Praunus flexuosus* (Mauchline 1980).

Adoption of larvae by ovigerous females has been observed in several species of mysid (Wittmann 1978, Mauchline 1980). Usually all the larvae within a brood pouch are at the same stage of development. In the thirteen cases in this study of

ovigerous *B. nobilis* with larvae of more than one developmental stage (Table 14), four brood pouches contained mostly stage one larvae with a few early stage two larvae; these larvae had probably developed a little faster than the rest of the individuals in the brood pouch and were probably not adopted. In the seven cases where there were large numbers of stage 2 larvae and one or two stage 1 larvae in the marsupia, it is likely that the stage 1 larvae were either dead or slow to develop. The incidence of adoption of larvae is not high. Wittmann (1978) estimated that 0.8% of ovigerous *Leptomysis lingvura* in Mediterranean populations, and 0.25% of ovigerous *L. burgii* from the northern Adriatic Sea carried one or more adopted larvae. Even if the single stage 3 larvae that I found in each of two brood pouches of stage 2 larvae were adopted and not merely early developers, only 0.2% of the ovigerous females showed evidence of adoption. Such a small percentage indicates that adoption does not contribute greatly to the survival of larvae.

5.7 Parasites

Although mysids are frequently encountered in plankton tows, their parasites and pathological conditions, particularly in the western North Atlantic, have not been extensively studied (Mauchline 1980). Cestodes, acanthocephalans and trematodes have been described from other mysids (e.g. Tattersall and Tattersall 1951, Brownell 1970, Shotter 1970, Amin 1978), but no parasitic worms were found in *Boreomysis*

nobilis in this study. Other metazoan parasites recorded from mysids are isopods (e.g. Tattersall and Tattersall 1951, Balasubrahmanyan and Prince 1976), copepods (e.g. Daly and Damkaer 1986) and leeches (e.g. Burreson and Allen 1978). There was no evidence of any of these parasites on *B. nobilis*.

The most frequently reported parasite of mysids is the ellobiopsid *Thalassomyces* spp. (Mauchline 1980). There is some confusion over the taxonomy of the Ellobiopsidae. They have been classified as fungi (Jepps 1937, Kane 1964), but the generally accepted classification is that of Wing (1975), who concluded that they are multinucleated Protista (*incertae sedis*).

The presence of *Thalassomyces boschmai* (Nouvel 1954) on *B. nobilis* in this study is a new host record. This parasite has been reported from a variety of mysid species from Alaska to the Mediterranean (Wing 1975), but has not been reported previously from Newfoundland waters. Electron micrographs of the parasite (Figures 18 and 19) show that the gonomeres have a pebbled appearance. Galt and Whisler (1970) report that in *T. marsupii* this pebbling is an indication of spore differentiation. Secondary faceting will occur on each "pebble" and eventually this progressive infolding will divide the gonomere into bunches of uninucleate spores (Galt and Whisler 1970); the spores are presumably infective to the host (Kane 1964).

The overall infection rate of *T. boschmai* on *B. nobilis* was relatively low (0.1%), although in areas where the parasite was found, infection rates ranged from 0.2% to 11.24%. The parasite was found only in specimens from Trinity Bay and the Bay of

Exploits. No *T. boschmai* was recorded from *B. nobilis* collected during the November 1986 cruise, but on that sampling trip, no collections were made in Trinity Bay. The predominance of the parasite in Trinity Bay, and its absence from all other bays sampled except for one individual from the Bay of Exploits, is puzzling. The low incidence of the parasite may mean that it is in other bays but just was not caught. However it is possible that because of the restricted geographical distribution of *B. nobilis* in Newfoundland fjords, there is little exchange of individuals, and hence their parasites, between populations in the different bays. If a spore of *T. boschmai* infected a *B. nobilis* in Trinity Bay, it would develop to maturity and spores would then be released into the Trinity Bay *B. nobilis* population; there would then be a greater tendency for the mysids in this population to become infected by the parasite. If there is little mixing between populations in the different bays, then the parasite would tend to remain largely in Trinity Bay and would be most common in individuals of that population. If, by chance, the spores of *T. boschmai* or a *B. nobilis* infected with a mature parasite were distributed to a new location, the parasite could become established in another bay, assuming that the physical conditions were suitable and the density of hosts sufficient.

Wing (1975) reported that less than 10% of the parasitized mysids he examined had more than one *T. boschmai*; Hoenigman (1954) found seven *T. boschmai* on one specimen of *Leptomysis gracilis*. However, in this study no *B. nobilis* were found to be infected with more than one *T. boschmai*.

Thalassomyces boschmai was always found on the carapace of its host and it penetrated through the cuticle into the thoracic tissue. The invasion of host tissue by *Thalassomyces* spp. has led to speculation that the parasite may sterilize its host (Mauchline 1980). When *Thalassomyces* spp. infects euphausiids it may not prevent the development of secondary sexual characteristics, but it does tend to hinder the development of the host's reproductive system (Mauchline 1980). This may not be the case for mysids since Nouvel and Hoenigman (1955) reported an infected female *Leptomysis gracilis* with a full brood, although her eggs may have been deposited prior to infection (Wing 1975). All the infected *B. nobilis* in this study were juveniles and immature males and females, and since no histological studies were made, the effect of the parasite on the development and reproductive capability of the host is unknown. All the infected *B. nobilis* were within the normal length range for their stage of development, and so the parasite did not seem to have interfered with their growth. However, such a large parasite which is firmly attached through the carapace of the host is almost certain to have some effect on moulting. It is possible that because *Thalassomyces* spp. is closely associated with the nervous system and gonadal tissues of the host, it may interfere with the host's production of the hormones which are necessary for ecdysis (Wing 1975).

Summary

1. *Boreomysis nobilis* is a large, hyperbenthic mysid with a two year life cycle.
2. *Boreomysis nobilis* was found in nine deep fjords around Newfoundland and was more common inside than outside the fjords. It was absent in some bays where physical parameters (depth, temperature, salinity) appeared suitable for its presence, suggesting that other factors were influencing the distribution.
3. Although *B. nobilis* is hyperbenthic and was found in the greatest density near the sea bottom, it was capable of moving over wide vertical distances in the water column. There was no evidence of diel vertical migration or differences in vertical zonation among the different life history stages.
4. *Boreomysis nobilis* breeds throughout the year. There is, however, evidence for a period of increased reproductive intensity in the late spring and summer. If the larvae of *B. nobilis* develop at a similar rate to larvae of other cold-water mysids, a peak in breeding in the early summer would result in the release of juveniles the following spring.
5. Mature male *B. nobilis* are larger than mature females. There is no evidence of seasonal variation in the size of males and females at sexual maturity, in brood size or in the proportion of ovigerous females carrying each of the different larval stages.
6. Adoption may occur in populations of *B. nobilis*. If the stage 3 larvae found

in two brood pouches of stage 2 larvae were not just maturing faster than the rest of the brood, then *B. nobilis* exhibits an adoption rate of 0.2%.

7. *Boreomysis nobilis* produces a smaller number of large eggs relative to its body volume than predicted for epipelagic and coastal mysids from the regression line calculated by Mauchline (1980). As suggested by Wittmann (1984) for other cold water epipelagic species, *B. nobilis* conforms more closely to the regression line calculated for meso- and bathypelagic species. This strategy of putting more energy into producing fewer large eggs results in larger juveniles which are better able to exploit a wide variety of food resources and escape predation.

8. The ellobiopsid parasite *Thalassomyces boschmai* is reported from *B. nobilis* and Newfoundland waters for the first time. The parasite was found on hosts from only two bays and the infection rate varied from 0% to 11.2%. The patchy distribution of the parasite may be result from the restricted geographical distribution of the host. *Thalassomyces boschmai* was found only on juveniles and immature males and females and so no conclusions can be drawn regarding its affect on the reproductive capability of the host. No other parasites were found on or in *B. nobilis*.

References

Allen, D.M. 1982. Autecology of the cryptic mysid crustacean, *Heteromysis formosa* S.I. Smith 1873, in a temperate estuary. Hydrobiologia 93: 1-7.

Amaratunga, T. and S. Corey. 1975. Life history of *Mysis stenolepis* Smith (Crustacea, Mysidacea). Can. J. Zool. 53: 942-952.

Amin, O.M. 1978. On the crustacean hosts of larval acanthocephelan and cestode parasites in southwestern Lake Michigan. J. Parasitol. 64: 842-845.

Angel, M.V. 1976. Windows into a sea of confusion: sampling limitations to the measurement of ecological parameters in oceanic mid-water environments. p.217-248. *In* N.R. Anderson and B.J. Zjuhuranec [ed.] Oceanic sound scattering prediction; Marine Science, 5., Plenum Publishing, New York, N.Y.

Astthorsson, O.S. 1984. The distribution and biology of mysids in Icelandic and subarctic waters as demonstrated by analysis of cod stomach contents. Sarsia 69: 107-116.

Astthorsson, O.S. 1985. Mysids occurring in the stomachs of cod caught in the Atlantic water south and west of Iceland. Sarsia 70: 173-178.

Astthorsson, O.S. 1990. Aspects of the biology of *Mysis oculata* on the west coast of Iceland. Ann. Zool. Fennici. 27: 247-251.

Astthorsson, O.S. and R. Ralph. 1984. Growth and moulting of *Neomysis integer* (Crustacea, Mysidacea). Mar. Biol. 79: 55-61.

Attramadal, Y.G., J.H. Fössa and H.L. Nilsson. 1985. Changes in behaviour and eye-morphology of *Boreomysis megalops* G.O. Sars (Crustacea: Mysidacea) following exposure to short periods of artificial and natural daylight. J. Exp. Mar. Biol. Ecol. 85: 135-148.

Balasubramanyan, K., and M.J. Prince. 1976. *Pradajus ovatus* Pillai (Isopoda) parasitic on a new host. Curr. Sci. 45: 603.

Banner, A.H. 1954. New records of Mysidacea and Euphausiacea from the northeastern Pacific and adjacent areas. Pac. Sci. 8: 125-139.

Beck, J.T. 1977. Reproduction of the estuarine mysid *Taphromysis bowmani*

(Crustacea: Malacostraca) in fresh water. Mar. Biol. 42: 253-257.

Bousfield, E.L. 1973. Shallow water Gammaridean Amphipoda of New England. Cornell University Press, New York, N.Y. 312 p.

Brattegard, T. 1973. Mysidacea from shallow water on the Caribbean coast of Colombia. Sarsia 54: 1-66.

Brattegard, T. 1974. Additional Mysidacea from shallow water on the Caribbean coast of Colombia. Sarsia 57: 47-86.

Brownell, W.N. 1970. Comparison of *Mysis relicta* and *Pontoporeia affinis* as possible intermediate hosts for the acanthocephelan *Echinorhynchus salmonis*. J. Fish. Res. Board Can. 27: 1864-1866.

Brunel, P. 1960. Artificial key to the Mysidacea of the Canadian Atlantic continental shelf. Can. J. Zool. 38: 851-855.

Burreson, E.M. and D.M. Allen. 1978. Morphology and biology of *Mysidobdella borealis* (Johansson) comb. n. (Hirudinea: Piscicolidea) from mysids in the western North Atlantic. J. Parasitol. 64: 1082-1091.

Childress, J.J. and M.H. Price. 1978. Growth rate of the bathypelagic crustacean *Gnathophausia ingens* (Mysidacea: Lophogastridae). 1. Dimensional growth and population structure. Mar. Biol. 50: 47-62.

Clutter, R.I. 1967. Zonation of nearshore mysids. Ecology 48: 200-208.

Daly, K.L. and D.M. Damkaer. 1986. Population dynamics and distribution of *Neomysis mercedis* and *Alienacanthomysis macropsis* (Crustacea: Mysidacea) in relation to the parasitic copepod *Hansenulus trebax* in the Columbia estuary. J. Crust. Biol. 6: 840-857.

Daly, K.L. and C. Holmquist. 1986. A key to the Mysidacea of the Pacific Northwest. Can. J. Zool. 38: 851-855.

Davis, C.C. 1986. A comparison of the zooplankton in two Newfoundland Bays with differing influences from major currents. Int. Revue. Ges. Hydrobiol. 71: 11-47.

Drainville, G. 1970. Le fjord du Saguenay. II. La faune ichtyologique et les conditions écologiques. Nat. Can. 97: 623-666.

Dunbar, M.J. 1940. On the size distribution and breeding cycles of four marine planktonic animals from the Arctic. J. Anim. Ecol. 9: 215-226.

Dunbar, M.J. 1941. On the food of seals in the Canadian Eastern Arctic. Can. J. Res. 19D: 150-155.

Dunbar, M.J. 1942. Marine macroplankton from the Canadian Eastern Arctic. I. Amphipoda and Schizopoda. Can. J. Res. 20D: 33-46.

Elseth, G.D. and K.D. Baumgardner. 1981. Population Biology. D. Van Nostrand Co., New York, N.Y. 623 p.

Emmel, T.C. 1976. Population Biology. Harper and Row, Publishers, Inc., New York, N.Y. 371 p.

Fleminger, A. and R.I. Clutter. 1965. Avoidance of towed nets by zooplankton. Limnol. Oceanog. 10: 96-104.

Fössa, J.H. 1985. Near-bottom vertical zonation during daytime of deep-living hyperbenthic mysids (Crustacea: Mysidacea). Sarsia 70: 297-307.

Fössa, J.H. 1986. Aquarium observations on vertical zonation and bottom relationships of some deep-living hyperbenthic mysids (Crustacea: Mysidacea). Ophelia 25: 107-117.

Galt, J.H. and H.C. Whisler. 1970. Differentiation of flagellated spores in *Thalassomyces* ellobiopsid parasite of marine Crustaceae. Archiv. fur Mikrobiol. 71: 295-303.

Geiger, S.R. 1969. Distribution and development of mysids (Crustacea, Mysidacea) from the Arctic Ocean and confluent seas. Bull. South. Calif. Acad. Sci. 68:103-111.

Greenwood, J.G., M.B. Jones and J. Greenwood. 1985. Reproductive biology, seasonality and distribution of *Tenagomysis macropsis* W. Tattersall, 1923 (Crustacea, Mysidacea) in a New Zealand estuary. Bull. Mar. Sci. 37: 538-555.

Haedrich, R.L. and N.R. Henderson. 1974. Pelagic food of *Coryphenoides armatus*, a deep benthic rattail. Deep-Sea Res. 21: 739-744.

Hesthagen, I.H. 1973. Diurnal and seasonal variations in the near-bottom fauna - the hyperbenthos - in one of the deeper channels of the Kieler Bucht (western

Baltic). Kieler Meeresforshungen 29: 116-140.

Hoenigman, J. 1954. Novosti s podrocja jadranskega zooplanktona. (O najdbi elobiopsidov). Bioloski Vestnik, Ljubljana 3: 106-116).

Houston, K.A. and R.L. Haedrich. 1986. Food habits and intestinal parasites of deep demersal fish from the upper continental slope east of Newfoundland, northwest Atlantic Ocean. Mar. Biol. 92: 563-574.

Isaacs, J.D. and L.W. Kidd. 1953. Isaacs-Kidd Midwater Trawl, Final Report. Oceanographic Equipment Report No. 1, University of California, Scripps Institution of Oceanography. 19p.

Jepps, M.W. 1937. On the protozoan parasites of *Calanus finmarchicus* in the Clyde Sea area. Quart. J. Micr. Sci. 79: 634-642.

Jepsen, J. 1965. Marsupial development of *Boreomysis arctica* (Kroyer, 1861). Sarsia 20: 1-8.

Judkins, D.C. and R. Wright. 1974. New records of the mysids *Boreomysis nobilis* G.O. Sars and *Mysis litoralis* (Banner) in the Saguenay fjord (St. Lawrence estuary). Can. J. Zool. 52: 1087-1090.

Kaartvedt, S. 1985. Diel changes in small-scale vertical distribution of hypobenthic mysids. Sarsia 70: 287-295.

Kaartvedt, S. 1989. Retention of vertically migrating suprabenthic mysids in fjords. Mar. Ecol. Prog. Ser. 57:119-128.

Kane, J.E. 1964. *Thalassomyces marsupii*, a new species of ellobiopsid parasite on the hyperiid amphipod *Parathemisto gaudichaudii* (Guer.). New Zeal. J. Sci. 7: 289-303.

Komaki, Y. 1970. On the parasitic organisms in a krill, *Euphausia similis*, from Suruga Bay. J. Oceanogr. Soc. Jap. 26: 283-295.

Lasenby, D.C. and R.R. Langford. 1972. Growth, life history and respiration of *Mysis relicta* in an Arctic and temperate lake. J. Fish. Res. Board Can. 29:1701-1708.

Lonsdale, D.J. and J.S. Levinton. 1985. Latitudinal differences in embryonic duration, egg size, and newborn survival in a harpacticoid copepod. Biol. Bull. 168: 419-431.

MacDonald, P.D.M. and T.J. Pitcher. 1979. Age-groups from size-frequency data: a versatile and efficient method of analyzing distribution mixtures. J. Fish. Res. Board Can. 36: 987-1001.

Marshall, N.B. 1953. Egg size in Arctic, Antarctic and deep-sea fishes. Evolution 7: 328-341.

Mauchline, J. 1965. Breeding and fecundity of *Praunus inermis* (Crustacea, Mysidacea). J. Mar. Biol. Ass. U.K. 45: 663-671.

Mauchline, J. 1967. The biology of *Schistomysis spiritus* (Crustacea, Mysidacea). J. Mar. Biol. Ass. U.K. 47: 383-396.

Mauchline, J. 1972. The biology of bathypelagic organisms, especially Crustacea. Deep-Sea Res. 19: 753-780.

Mauchline, J. 1973. The broods of British Mysidacea (Crustacea). J. Mar. Biol. Ass. U.K. 53: 801-817.

Mauchline, J. 1980. The biology of mysids. Adv. Mar. Biol. 18: 3-369.

McLaren, I.A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. J. Fish. Res. Bd. Can. 118: 1-97.

McLaren, I.A. 1966. Predicting development rate of copepod eggs. Biol. Bull. 131: 457-469.

Nouvel, H. and J. Hoenigman. 1955. *Amallocystis boschmai* Nouvel 1954 ellobiopside parasite du mysidace *Leptomysis gracilis* G.O. Sars. Res. Camp. Pr. Lacuze-Duthiers, Vol. 2. Vie et Milieu, Supp. 6: 1-18.

Petrie, B. and C. Anderson. 1983. Circulation on the Newfoundland Continental Shelf. Atmos. Ocean. 21: 207-226.

Pomeroy, L.R. and D. Diebel. 1986. Temperature regulation of bacterial activity during the spring bloom in Newfoundland coastal waters. Science 233: 259-261.

Raymont, J.E.G. 1983. Plankton and productivity in the Oceans. II. Zooplankton. Plenum Publishing Co., Inc., New York, N.Y. 432p.

Richard, J.M. 1987. The mesopelagic fish and invertebrate macrozooplankton faunas of two Newfoundland fjords with differing physical oceanography. M.Sc. Thesis, Memorial University of Newfoundland. 161 p.

Richard, J.M. and R.L. Haedrich. 1991. A comparison of the macrozooplankton faunas in two Newfoundland fjords differing in physical oceanography. Sarsia 76: 41-52.

Rudstam, L.G. and S. Hansson. 1989. On the ecology of *Mysis mixta* (Crustacea, Mysidacea) in a coastal area of the northern Baltic proper. Ann. Zool. Fennici 27:259-263.

Russell-Hunter, W.D. 1969. A biology of higher invertebrates. Macmillan Publishing Co., Inc., New York, N.Y. 224 p.

Sanger, G.A. 1987. Winter diets of common murres and marbled murrelets in Kachemak Bay, Alaska. The Condor 89: 426-430.

Sars, G.O. 1879. Crustacea et Pycnogonida Nova in Itere 2D0 et 3T10 Expiditionis Norvegicae anno 1877 et 78 collecta. Archiv fur Mathematik og. Naturridenskab 4: 427-476.

SAS Institute, Inc. 1985. SAS User's Guide: Basics, Version 5 Edition. SAS Institute Inc., Cary, N.C. 1290p.

Sergeant, D.E. 1973. Feeding, growth and productivity of northwest Atlantic harp seals (*Pagophilus groenlandicus*). J. Fish. Res. Board Can. 30: 17-29.

Schram, F.R. 1986. Crustacea. Oxford University Press, New York, New York. 606p.

Shih, C-T., and D.R. Laubitz. 1978. Zooplankton distribution in the eastern Beaufort Sea and the Northwest Passage. Astarte 11: 45-54.

Shotter, R.A. 1970. A new second intermediate host, *Schistomysis spiritus* (Sars), for the digenean, *Podoctyl atomon* (Rudolphi). Rep. Mar. Biol. Stn., Port Errin 82: 35-37.

Steele, D.H. 1977. Correlation between egg size and developmental period. Am. Nat. 111: 371-372.

Steele, D.H. and V.J. Steele. 1975. Egg size and duration of embryonic development in Crustacea. Int. Revue. Ges. Hydrobiol. 60: 711-715

Stephensen, K. 1933. The Godthaab Expedition 1928: Schizopoda. Meddelelser om Gronland 79: 1-20.

Talley, L.D. and M.S. McCartney. 1982. Distribution and circulation of Labrador Sea Water. Am. Meteorol. Soc. 12: 1189-1205.

Tattersall, W.M. 1939. The Mysidacea of Eastern Canadian waters. J. Fish. Res. Board Can. 4: 281-286.

Tattersall, W.M. 1951. A review of the Mysidacea of the United States National Museum. Bull. U.S. Nat. Mus. 201: 1-292.

Tattersall, W.M. and O.S. Tattersall. 1951. The British Mysidacea. The Ray Society, London. 460 p.

Thorson, G. 1950. Reproductive and larval ecology of marine bottom invertebrates. Biol. Rev. 25: 1-45.

Thresher, R.E. 1988. Latitudinal variation in egg sizes of tropical and sub-tropical North Atlantic shore fishes. Environ. Biol. Fishes 21: 17-25.

Toda, H., A. Toshiyuki, M Takahashi and S. Ichimura. 1987. Physiological evaluation of temperature effect on the growth processes of the mysid, *Neomysis intermedia* Czerniawsky. J. Plank. Res. 9: 51-63.

Weslawski, J.M. 1989. Occurrence and life cycle of *Mysis oculata* (Crustacea) from Spitsbergen. Pol. Arch. Hydrobiol. 36:207-215.

Wing, B.L. 1975. New records of Ellobiopsidae (Protista (*incertae sedis*)) from the North Pacific with a description of *Thalassomyces albatrossi* n.sp., a parasite of the mysid *Stilomysis major*. Fish. Bull. 73: 169-185.

Wittmann, K.J. 1978. Adoption, replacement and identification of young in marine Mysidacea (Crustacea). J. Exp. Mar. Biol. Ecol. 32: 259-274.

Wittmann, K.J. 1981. On the breeding biology and physiology of marsupial development in Mediterranean *Leptomysis* (Mysidacea: Crustacea) with special reference to the effects of temperature and egg size. J. Exp. Mar. Biol. Ecol. 53:261-279.

Wittmann, K.J. 1984. Ecophysiology of marsupial development and reproduction in Mysidacea (Crustacea). Oceanogr. Mar. Biol. Ann. Rev. 22: 393-428.

Wright, R.A. 1972. Occurrence and distribution of the Mysidacea of the Gulf of St. Lawrence. M.Sc. Thesis, McGill University. 200 p.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 718 p.

Table 1: Details for stations where Boreomysis nobilis were caught during four research cruises: Dawson 86–026, Templeman–54, Baffin 87–016 and Dawson 87–030. Tow depth indicates the maximum depth at which the net was fished for oblique tows and the average depth at which the net was fished for horizontal tows.

STATION	BAY	LATITUDE (°N)	LONGITUDE (°W)	NET	TYPE	DEPTH (m)	TOW DEPTH (m)	TEMP (°C)	SALINITY (ppt)
1751	White	49°58.4'	56°46.0'	10'	Horizontal	492	135	−0.3	32.4
1754	Exploits	49°30.4'	55°07.6'	10'	Horizontal	500	190	−1	33.1
1755	Exploits	49°31.3'	55°07.4'	10'	Horizontal	500	330	−1.1	33.2
1756	Exploits	49°31.3'	55°07.4'	10'	Horizontal	500	300	−1.1	33.2
1757	Hall	49°35.9'	55°48.2'	10'	Horizontal	480	145	−1.3	32.9
1758	Hall	49°37.0'	55°47.2'	10'	Horizontal	457	220	−0.6	33.4
1759	Hall	49°38.3'	55°44.1'	10'	Horizontal	457	51	−0.6	32.4
1766	Trinity	48°01.5'	53°22.8'	10'	Horizontal	567	200	−0.1	33.4
1767	Trinity	48°01.3'	53°22.7'	10'	Horizontal	567	160	−0.5	33.3
1768	Trinity	48°00.6'	53°23.7'	10'	Horizontal	567	70	−0.8	32.4
1805	White	50°09.8'	56°22.8'	Bongo	Oblique	363	235	−1.1	33
1806	White	49°58.6'	56°35.2'	Bongo	Oblique	491	420	0.2	33.8
1807	White	49°58.6'	56°35.3'	Bongo	Oblique	492	344	0.1	33.7
1808	White	49°58.5'	56°35.2'	6'	Horizontal	489	300	−0.9	33.4
1812	White	49°59.6'	56°33.7'	6'	Horizontal	468	290	−1	33.3
1815	Notre Dame	49°51.6'	54°58.8'	6'	Horizontal	370	280	−1.1	33.2
1818	Green	49°43.8'	55°57.2'	6'	Horizontal	414	240	−0.9	33.1
1819	Green	49°44.5'	55°53.9'	Bongo	Oblique	442	300	−0.8	33.3
1820	Green	49°44.4'	55°54.1'	Bongo	Oblique	436	300	−0.8	33.3
1821	Green	49°44.1'	55°55.1'	Bongo	Oblique	437	230	−0.8	33.3
1822	Green	49°44.0'	55°55.5'	6'	Horizontal	414	270	−0.8	33.2
1823	Hall	49°33.0'	55°53.4'	6'	Horizontal	453	230	−1.1	33.2

Table 1 continued

STATION	BAY	LATITUDE (°N)	LONGITUDE (°W)	NET	TYPE	DEPTH (m)	TOW DEPTH (m)	TEMP (°C)	SALINITY (ppt)
1824	Hall	49°33.6'	55°51.4'	Bongo	Oblique	437	250	−1	33.3
1825	Hall	49°33.6'	55°51.3'	Bongo	Oblique	440	250	−1	33.3
1826	Badger	49°30.4'	55°33.4'	6'	Horizontal	440	260	−1.1	33.3
1828	Badger	49°29.7'	55°35.9'	Bongo	Oblique	439	325	−1.1	33.3
1829	New	49°28.0'	55°18.6'	6'	Horizontal	433	275	−1	33.3
1830	New	49°29.3'	55°19.2'	Bongo	Oblique	414	250	−1	33.3
1831	New	49°29.2'	55°19.2'	Bongo	Oblique	436	250	−1	33.3
1832	Exploits	49°23.4'	55°09.2'	6'	Horizontal	506	325	−1.2	33.4
1833	Exploits	49°23.0'	55°09.2'	6'	Horizontal	557	190	−1.2	33
1834	Exploits	49°24.6'	55°09.2'	6'	Horizontal	537	40	2.8	31.8
1839	Bonavista	48°41.2'	53°31.5'	6'	Horizontal	455	230	−1.2	33.2
1840	Bonavista	48°34.6'	53°32.6'	Bongo	Oblique	375	195	−1.2	33.1
1902	Trinity	48°00.4'	53°23.5'	10'	Horizontal	575	550	0.8	34
1903	Trinity	48°00.2'	53°23.7'	Bongo	Horizontal	574	525	0.8	34
1904	Trinity	48°00.5'	53°23.9'	Bongo	Horizontal	561	450	0.6	34
1905	Trinity	48°02.7'	53°23.7'	Bongo	Oblique	615	400	0.6	34
1906	Trinity	48°04.6'	53°20.9'	Bongo	Horizontal	570	525	0.8	34
1907	Exploits	49°31.2'	55°07.8'	Bongo	Horizontal	540	361	−0.9	33.5
1908	Exploits	49°29.4'	55°06.9'	Bongo	Horizontal	623	522	−0.7	33.5
1909	Exploits	49°26.9'	55°07.3'	Bongo	Horizontal	615	557	−0.8	33.5
1910	Exploits	49°29.0'	55°05.9'	Bongo	Horizontal	632	488	−0.7	33.5
1911	Exploits	49°31.0'	55°07.4'	Bongo	Horizontal	635	471	−0.8	33.5
1912	Exploits	49°29.1'	55°07.1'	Bongo	Oblique	625	575	−0.6	33.5

Table 1 continued

STATION	BAY	LATITUDE (°N)	LONGITUDE (°W)	NET	TYPE	DEPTH (m)	TOW DEPTH (m)	TEMP (°C)	SALINITY (ppt)
1913	Exploits	49°27.8'	55°06.5'	Bongo	Horizontal	613	426	−0.8	33.5
1914	White	50°01.4'	56°30.0'	Bongo	Horizontal	423	271	−0.2	33.6
1915	White	50°01.1'	56°33.2'	Bongo	Horizontal	425	345	0.1	33.8
1916	White	49°59.2'	56°34.5'	Bongo	Horizontal	470	438	0.6	33.9
1917	White	49°59.6'	56°32.2'	Bongo	Oblique	480	358	0.3	33.8
2007	Trinity	48°02.7'	53°21.4'	Bongo	Horizontal	571	466	1.6	34
2008	Trinity	48°00.7'	53°23.8'	Bongo	Horizontal	571	469	1.8	34
2009	Trinity	48°03.0'	53°20.6'	Bongo	Horizontal	571	512	2.2	34
2010	Trinity	48°01.0'	53°23.5'	Bongo	Oblique	568	545	1.9	34
2011	Trinity	48°08.8'	53°21.5'	10'	Horizontal	270	395	1.5	34
2012	Exploits	49°26.6'	55°08.0'	Bongo	Horizontal	604	445	−0.8	33.3
2013	Exploits	49°28.6'	55°06.6'	Bongo	Horizontal	536	456	−0.9	33.3
2014	Exploits	49°30.8'	55°07.8'	Bongo	Horizontal	632	507	−0.8	33.3
2015	Exploits	49°27.5'	55°06.8'	Bongo	Oblique	627	580	−0.8	33.3
2016	Exploits	49°30.3'	55°07.4'	10'	Horizontal	605	480	−0.8	33.3
2018	White	49°55.1'	56°39.2'	10'	Horizontal	475	437	0.8	33.8
2019	White	49°58.5'	56°35.3'	Bongo	Horizontal	482	414	0.7	33.8
2020	White	49°56.2'	56°37.1'	Bongo	Horizontal	496	434	0.8	33.8
2021	White	49°54.5'	56°39.0'	Bongo	Horizontal	507	389	0.6	33.7
2022	White	49°57.9'	56°35.9'	Bongo	Oblique	490	455	0.8	33.8
2023	Bonne	49°30.8'	57°50.2'	10'	Horizontal	229	200	−0.6	33.4
2024	Bonne	49°30.6'	57°50.0'	Bongo	Horizontal	237	203	−0.4	33.4

Table 2: Details for stations where B. nobilis were not caught during four research cruises: Dawson 86–026, Templeman–54, Baffin 87–016 and Dawson 87–030. Tow depth indicates the maximum depth at which the net was fished for oblique tows and the average depth at which the net was the net was fished for horizontal tows.

STATION	BAY	LATITUDE (°N)	LONGITUDE (°W)	NET	TYPE	DEPTH (m)	TOW DEPTH (m)	TEMP (°C)	SALINITY (ppt)
1750	White	49°36.2'	56°41.7'	10'	Horizontal	211	80	2.2	31.4
1752	St. Barbe	50°14.7'	55°17.9'	10'	Horizontal	310	155	−1.3	33.2
1753	Exploits	49°30.4'	55°07.6'	10'	Horizontal	360	80	−0.6	32.2
1760	Notre Dame	50°01.6'	54°17.8'	10'	Horizontal	355	200	−0.5	33.7
1761	Notre Dame	50°02.1'	54°16.5'	10'	Horizontal	310	145	−1.1	33.3
1762	Notre Dame	50°03.3'	54°15.4'	10'	Horizontal	320	65	−0.9	32.8
1763	Newman Sd	48°36.2'	53°47.4'	10'	Horizontal	280	170	−0.4	33.3
1764	Newman Sd	48°37.1'	53°45.4'	10'	Horizontal	310	120	−1.2	33
1765	Newman Sd	48°37.3'	53°43.3'	10'	Horizontal	310	40	2	32
1769	Conception	47°43.4'	53°09.5'	10'	Horizontal	273	220	−1	33.3
1770	Conception	47°37.0'	53°07.6'	10'	Horizontal	265	180	−1.2	33.2
1771	Conception	47°37.2'	53°07.5'	10'	Horizontal	265	40	2.8	32
1800	Conception	47°36.1'	53°07.6'	Bongo	Oblique	283	150	−1	32.8
1801	Conception	47°39.6'	53°07.0'	6'	Horizontal	222	170	−1	32.9
1802	St. Barbe	50°14.5'	55°18.4'	6'	Horizontal	309	172	−0.8	33.2
1803	St. Barbe	50°15.0'	55°22.0'	6'	Horizontal	309	140	−0.7	33.2
1804	White	50°09.8'	56°22.8'	Bongo	Oblique	363	235	−1.2	33
1809	White	49°57.8'	56°35.2'	6'	Horizontal	492	210	−1	33
1810	White	49°45.0'	56°44.2'	Bongo	Oblique	380	170	−0.5	32.8
1811	White	49°45.0'	56°44.1'	Bongo	Oblique	302	160	−0.2	32.7
1813	Notre Dame	49°51.4'	54°57.7'	Bongo	Oblique	391	250	−1.1	33.2
1814	Notre Dame	49°51.3'	54°58.4'	Bongo	Oblique	394	285	−1.1	33.3

Table 2 continued

STATION	BAY	LATITUDE (°N)	LONGITUDE (°W)	NET	TYPE	DEPTH (m)	TOW DEPTH (m)	TEMP (°C)	SALINITY (ppt)
1816	Notre Dame	49°45.8'	55°26.8'	Bongo	Oblique	263	170	−0.3	33
1817	Notre Dame	49°45.7'	56°26.7'	Bongo	Oblique	263	170	−0.3	33
1827	Badger	49°29.9'	55°36.0'	Bongo	Oblique	440	260	−1.1	33.3
1835	Exploits	49°16.8'	55°12.6'	6'	Horizontal	258	150	−1	32.8
1837	Bonavista	48°45.8'	53°26.2'	Bongo	Oblique	318	195	−1.1	33
1838	Bonavista	48°45.1'	53°26.4'	Bongo	Oblique	319	195	−1.1	33
1841	Bonavista	48°34.6'	53°32.6'	Bongo	Oblique	357	195	−1.2	33.1
1900	Conception	47°38.4'	53°05.6'	10'	Horizontal	268	175	−1.1	33.2
1901	Conception	47°38.8'	53°05.9'	10'	Horizontal	265	180	−1.1	33.2
1918	Bay of Islands	49°09.5'	58°20.0'	Bongo	Horizontal	243	186	0.9	32.4
1919	Bay of Islands	49°09.6'	58°17.8'	Bongo	Horizontal	233	157	0.7	32.4
1920	Bay of Islands	49°09.6'	58°20.3'	Bongo	Horizontal	255	221	0.9	32.5
1921	Bay of Islands	49°09.6'	58°19.7'	Bongo	Oblique	280	270	0.9	32.5
2001	Conception	47°53.2'	52°44.5'	Bongo	Horizontal	215	140	−1.2	32.8
2002	Conception	47°37.9'	53°06.3'	10'	Horizontal	285	224	−0.9	33.3
2003	Conception	47°40.4'	53°04.6'	10'	Horizontal	275	181	−1	33.2

Table 3: Details of the four scientific research cruises during which samples were collected for this study

Cruise Number	Dates	Locations	Net Used	No. Tows	Total No. Tows
Dawson 86–026	Sept. 3–10, 1986	Northeast Coast	10' IKMT	22	22
Templeman–54	Nov. 15–22, 1986	Northeast Coast	6' IKMT	16	
			Bongos	25	41
Baffin 87–016	May 22–29, 1987	Northeast Coast	10' IKMT	3	
		& Bay of Islands	Bongos	19	22
Dawson 87–030	Aug. 10–18, 1987	Northeast Coast	10' IKMT	6	
		& Bonne Bay	Bongos	14	20

Table 4: Station locations from Fortune Bay, May 1982 and June 1983. This table includes B. nobilis from Fortune Bay that were examined for parasites (Number of B. nobilis), and the number of ovigerous females that were used in the examination of the broods.

Station	Latitude (°N)	Longitude (°W)	Date	Number of *B. nobilis*	Number of Ovigerous Females
1215	47°24.0'	55°27.6'	May 82	81	2
1408	47°37.3'	55°16.7'	June 83	1	0
1409	47°38.8'	55°24.5'	June 83	37	0
1410	47°41.2'	55°25.1'	June 83	574	39
1411	47°20.7'	55°36.3'	June 83	13	0
1413	47°22.1'	55°32.2'	June 83	62	3
1414	47°22.4'	55°30.1'	June 83	2	0

Table 5: Catch rates (number of B. nobilis caught per minute per metre of net mouth opening squared) for all stations at which B. nobilis was caught.

Station	# *B. nobilis* Caught	Tow Length (mins.)	Catch Rate (no./min/m^2)
1751	7	32	0.03
1754	71	41	0.22
1755	112	52	0.28
1756	721	40	2.31
1757	3	38	1.62
1758	146	45	0.42
1759	7	30	0.03
1766	164	30	0.7
1767	113	33	0.44
1768	21	33	0.08
1805	1	25	0.14
1806	69	26	9.09
1807	10	38	0.9
1808	1	31	0.11
1812	176	11	5.52
1815	20	40	0.17
1818	624	38	5.66
1819	52	27	6.59
1820	348	27	44.13
1821	7	22	1.09
1822	398	48	2.86
1823	106	38	0.96
1824	25	21	4.08
1825	10	19	1.8
1826	13	49	0.09
1828	2	16	0.43
1829	30	39	2.63
1830	2	24	0.29
1831	17	22	2.65
1832	779	41	6.55
1833	80	40	0.69
1834	1	33	0.01
1839	2	38	0.02

Table 5 continued

Station	# *B. nobilis* Caught	Tow Length (mins.)	Catch Rate (no./min/m^2)
1840	5	16	1.07
1902	1653	51	4.16
1903	243	54	7.7
1904	347	62	9.58
1905	288	47	10.49
1906	240	38	10.81
1907	101	51	3.39
1808	119	49	4.16
1909	291	52	9.58
1910	218	51	7.32
1911	106	52	3.49
1912	175	35	8.56
1913	76	47	2.77
1914	11	45	0.42
1915	34	48	1.21
1916	482	49	16.84
1917	2	13	0.26
2007	616	59	17.87
2008	536	75	12.23
2009	513	73	12.03
2010	237	32	12.68
2011	3481	72	6.2
2012	240	59	6.96
2013	148	51	4.97
2014	161	67	4.11
2015	133	46	4.95
2016	875	46	2.44
2018	4035	72	7.19
2019	337	55	10.49
2020	397	56	12.14
2021	220	80	4.71
2022	151	43	6.01
2023	1517	49	3.97
2024	1304	50	44.64

Table 6: Depths (m) at which B. nobilis was caught and the depths at the mouths of the bays.

Bay	B. nobilis Caught Depth (m)	Mouth of Bay Depth (m)
White	363 – 507	308 – 326
Green	414 – 442	234 – 277
Hall	437 – 480	183 – 235
Badger	439 – 400	228 – 360
New	414 – 436	194 – 232
Exploits	500 – 635	203 – 217
Bonavista	375 – 455	152 – 232
Trinity	415 – 615	228 – 275
Bonne	229 – 237	109

Table 7: Minimum, maximum and mean lengths (mm) of B. nobilis caught by the six foot IKMT, the ten foot IKMT and the bongo nets.

	6' IKMT	10' IKMT	Bongos
Number	2201	12928	8303
Minimum Length (mm)	7.6	6.4	6.6
Maximum Length (mm)	44.2	49.2	45.5
Mean Length (mm)	30.1	30.8	24.2
Standard Deviation	4.7	11.4	9.1

Table 8: Minimum, maximum and mean lengths (mm) of B. nobilis caught by horizontal and oblique tows using the bongo nets. This table only includes data from the Baffin 87–016 and Dawson 87–030 cruises.

	Horizontal	Oblique
Number Caught	6788	938
Minimum Length (mm)	6.6	7.4
Maximum Length (mm)	45.5	44.9
Mean Length (mm)	24	25.1
Standard Deviation	8.2	9.2

Table 9: The percent of the total wet weight (g) by depth (m) that B. nobilis comprises. This table includes all the data from all stations and all types of nets.

Number of Stations	Depth	Percent Wet Weight	Standard Deviation
14	50	20.6	8.7
16	100	1.8	2.8
24	150	3.9	7.4
18	200	7.4	7.8
6	250	10.9	6.1
2	300	0.1	0.2
1	400	7.9	
1	500	0.1	

Table 10: Stations in White Bay used in the comparison of length–frequency distributions of the six life history stages.

Station	Latitude (°N)	Longitude (°W)	Depth (m)	Tow Depth (m)
1806	49°58.6'	56°35.2'	491	420
1807	49°58.5'	56°35.3'	492	344
1914	50°01.4'	56°30.0'	423	271
1915	50°01.1'	56°33.2'	425	345
1916	49°59.2'	56°34.5'	470	438
2019	49°58.5'	56°35.3'	482	414
2020	49°56.2'	56°37.1'	496	434
2021	49°54.5'	56°39.0'	507	389
2022	49°57.9'	56°35.9'	490	455

Table 11: The minimum total lengths (mm) of males and females at sexual maturity and the ratio of males to females for samples collected from the four different cruises.

Cruise	Month	Minimum Size (mm) Male	Female	Male:Female
Dawson 86–026	August	23.3	26.6	1:1.2
Templeman–54	November	25.8	26.2	1:1.3
Baffin 87–016	May	25.7	27.6	1:1.0
Dawson 87–030	August	19.5	25	1:1.1

Table 12: Numbers of ovigerous females with larvae at the three different stages of development at three different times of the year.

		November	May	August
Larval Stage 1	No. Ovigerous Females	7	42	79
	Minimum No. Larvae	22	14	10
	Maximum No. Larvae	33	39	43
	Mean No. Larvae	27	23	25
	Standard Deviation	4	4	5
Larval Stage 2	No. Ovigerous Females	5	104	209
	Minimum No. Larvae	20	15	12
	Maximum No. Larvae	33	31	37
	Mean No. Larvae	24	21	23
	Standard Deviation	5	4	4
Larval Stage 3	No. Ovigerous Females	2	23	56
	Minimum No. Larvae	8	6	9
	Maximum No. Larvae	20	30	27
	Mean No. Larvae	14	15	18.5
	Standard Deviation	8	6	4

Table 13: The mean, minimum and maximum lengths (mm) and standard deviation (S.D.) of ovigerous B. nobilis and their mean brood size, egg diameter (mm) and pouch volume (mm).

	Length (mm)	Brood Size	Egg Diameter (mm)	Pouch Volume (mm)
Maximum	40.4	39	1.8	83.6
Minimum	30.6	9	1.4	23
Mean	35.1	22.8	1.6	47.5
S.D.	1.6	4.9	0.1	10.7

Table 14: Brood pouches containing larvae of more than one developmental stage and the stations at which the ovigerous females were caught.

Station	Number of Stage 1	Number of Stage 2	Number Of Stage 3
1755	21	2	
1902	16	6	
1909		7	1
2011	16	2	
2013		17	1
2018	1	12	
2018	1	7	
2023	1	23	
2023	2	14	
2023	14	2	
2023	2	20	
2023	1	19	
2024	1	21	

Table 15: Boreomysis nobilis infected with Thalassomyces boschmai. Minimum and maximum lengths refer to the average minimum and maximum lengths of all B. nobilis from the same station and at the same stage of development as the infected mysid.

Bay	Station	Length (mm)	Stage	Minimum Length (mm)	Maximum Length (mm)
Trinity	1766	12.0	Juvenile	10.9	28.4
Trinity	1766	16.5	Juvenile	10.9	28.4
Trinity	1766	12.1	Juvenile	10.9	28.4
Trinity	1766	14.0	Juvenile	10.9	28.4
Trinity	1766	24.2	Immature Male	20.3	32.7
Trinity	1766	22.6	Immature Male	20.3	32.7
Trinity	1766	23.3	Immature Male	20.3	32.7
Trinity	1766	30.1	Immature Male	20.3	32.7
Trinity	1766	31.4	Immature Male	20.3	32.7
Trinity	1766	32.2	Immature Male	20.3	32.7
Trinity	1766	25.2	Immature Female	18.2	35.9
Trinity	1766	29.2	Immature Female	18.2	35.9
Trinity	1766	24.1	Immature Female	18.2	35.9
Trinity	1766	24.5	Immature Female	18.2	35.9
Trinity	1766	28.9	Immature Female	18.2	35.9
Trinity	1766	27.3	Immature Female	18.2	35.9
Trinity	1766	28.2	Immature Female	18.2	35.9
Trinity	1766	23.1	Immature Female	18.2	35.9
Trinity	1766		loose		
Trinity	1767	16.5	Juvenile	8.8	26.2
Trinity	1902	25.0	Immature Male	16.1	35.7
Trinity	1902	28.6	Immature Female	16.5	40.0
Trinity	1902	32.3	Immature Female	16.5	40.0
Trinity	1904	29.2	Immature Male	18.2	38.6
Trinity	1904	30.4	Immature Male	18.2	38.6
Trinity	1904	29.5	Immature Female	17.5	35.1

Table 15 continued

Bay	Station	Length (mm)	Stage	Minimum Length (mm)	Maximum Length (mm)
Trinity	1904	28.1	Immature Female	17.5	35.1
Trinity	1905	27.2	Immature Male	15.6	35.1
Trinity	1906	30.8	Immature Male	17.1	35.8
Trinity	1906	33.6	Immature Male	17.1	35.8
Trinity	1906	33.1	Immature Female	14.4	37.4
Exploits	1909	36.7	Immature Female	18.2	36.7
Trinity	2008	31.1	Immature Female	13.1	37.6
Trinity	2009	25.2	Immature Male	16.4	31.2
Trinity	2009	29.6	Immature Female	16.2	38.5

Figure 1: A mature male *Boreomysis nobilis*.

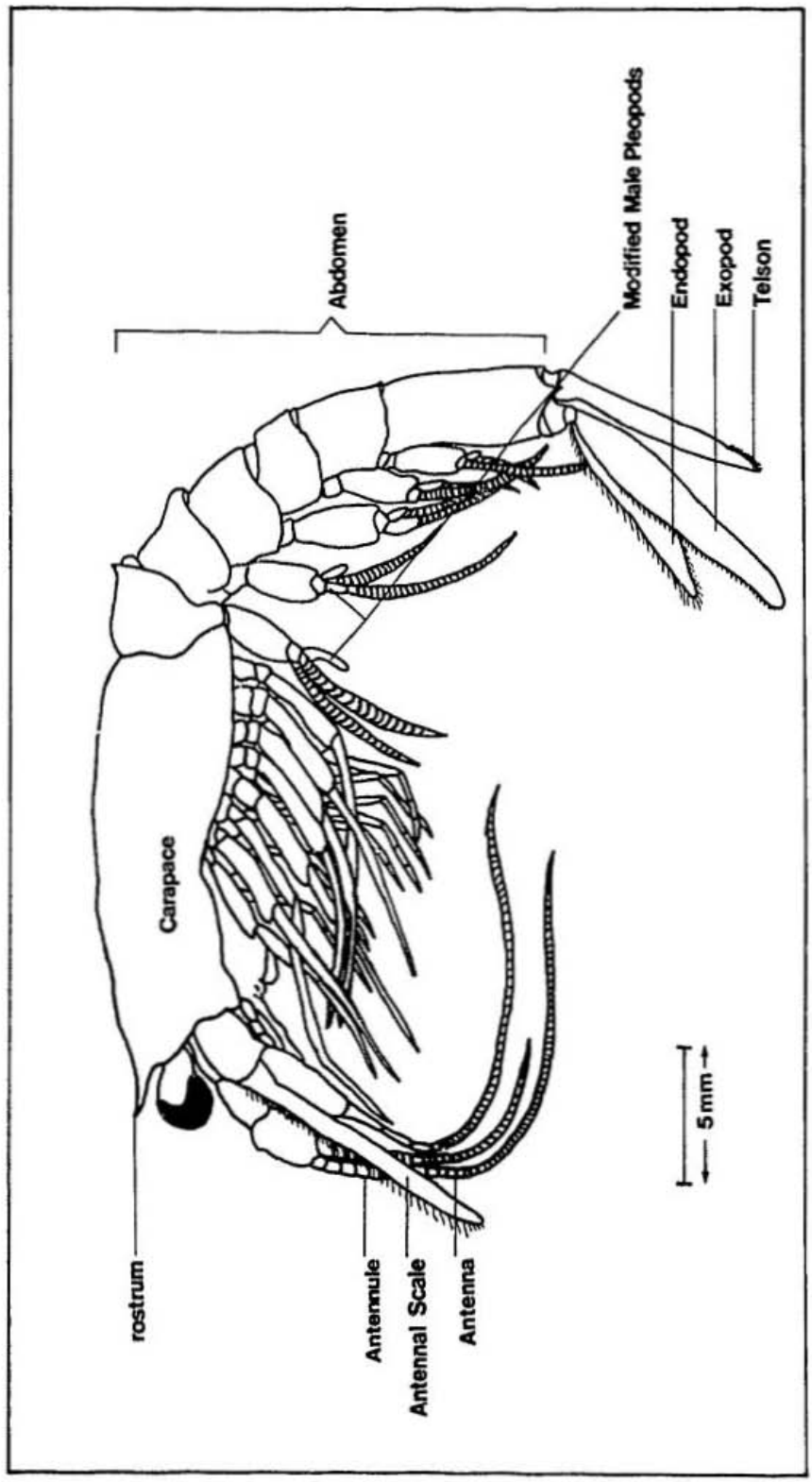

Abdomen
Modified Male Pleopods
Endopod
Exopod
Telson
Carapace
5 mm
rostrum
Antennule
Antennal Scale
Antenna

Figure 2: Locations in southeastern Canadian waters where *Boreomysis nobilis* were found prior to this study. Number 1 indicates the Saguenay Fjord, 2 is Bonne Bay, 3 is the Bay of Islands, 4 is the Bay of Exploits and 5 is Fortune Bay.

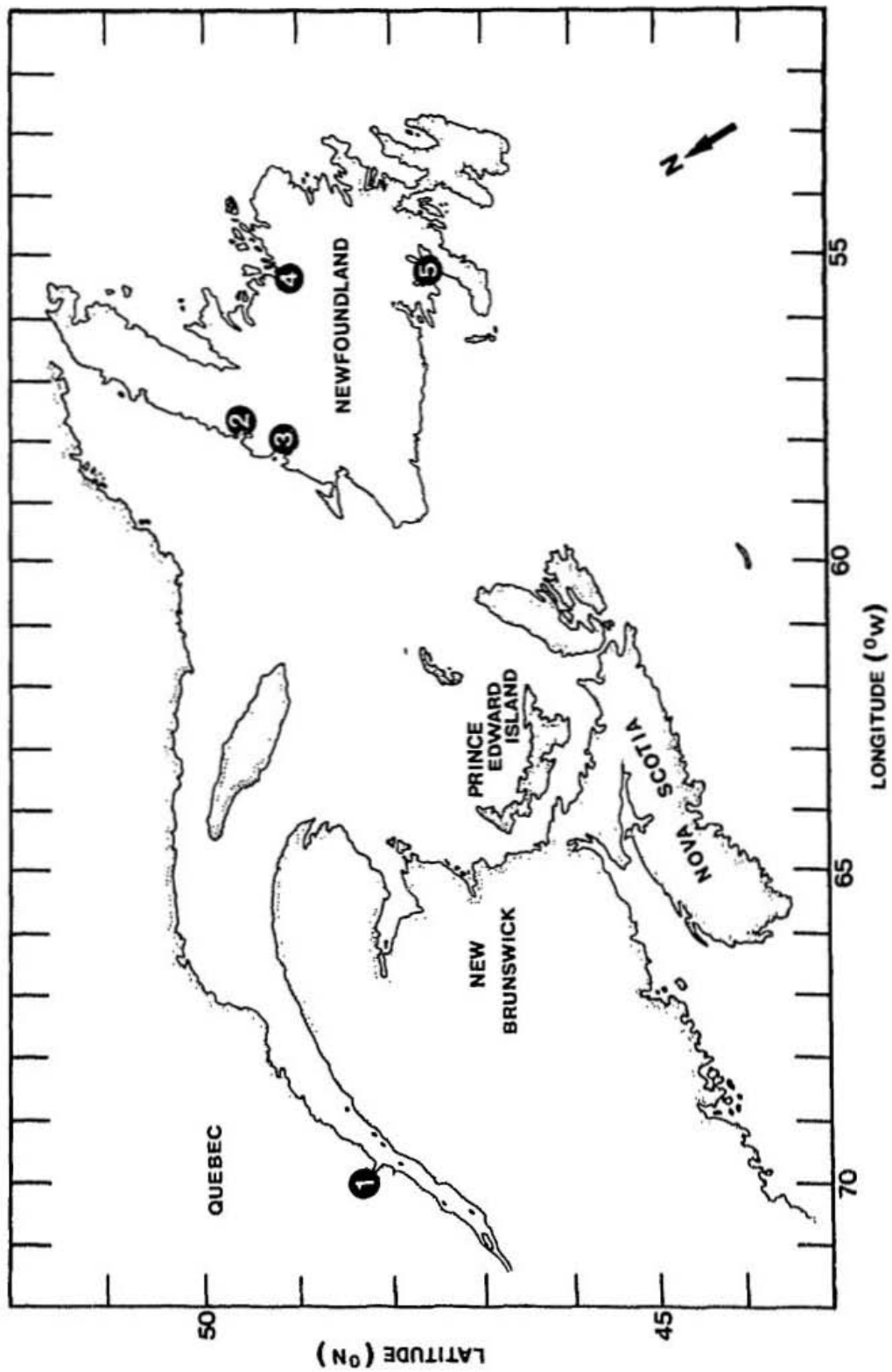

QUEBEC
NEWFOUNDLAND
NEW BRUNSWICK
PRINCE EDWARD ISLAND
NOVA SCOTIA
1
2
3
4
5
N
50
45
70
65
60
55
LATITUDE (°N)
LONGITUDE (°W)

Figure 3: Map of Newfoundland showing station locations from this study. Black circles indicate stations where *B. nobilis* was caught and open circles indicate stations where it was not caught. The area marked by box A is enlarged in Figure 4 and the area marked by box B is enlarged in Figure 5.

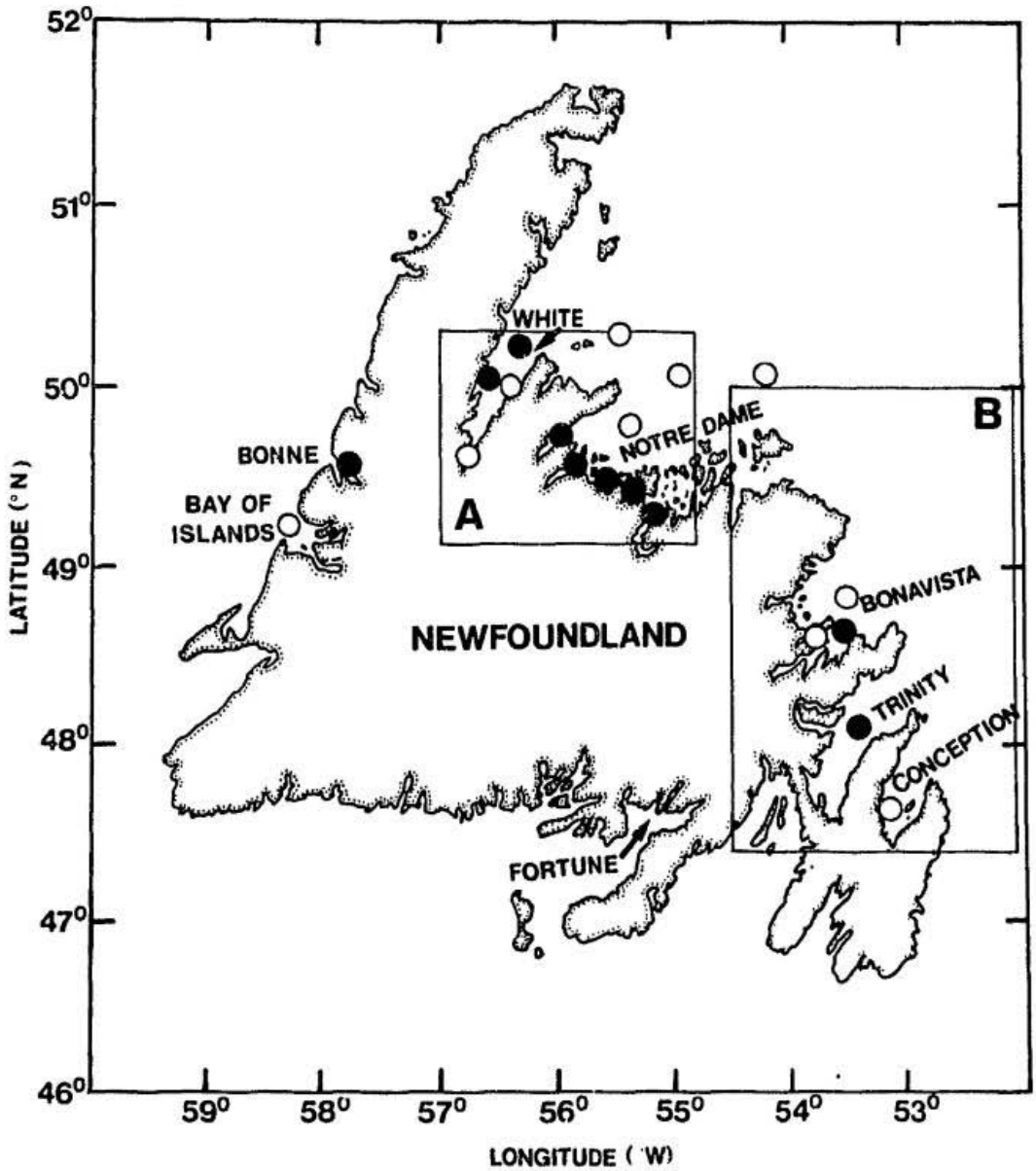

52°
51°
50°
49°
48°
47°
46°
59°
58°
57°
56°
55°
54°
53°
LATITUDE (°N)
LONGITUDE (°W)
WHITE
BONNE
BAY OF ISLANDS
NOTRE DAME
A
B
NEWFOUNDLAND
BONAVISTA
TRINITY
CONCEPTION
FORTUNE

Figure 4: Map of White and Notre Dame Bays showing station locations. Black circles indicate where *B. nobilis* were caught and open circles indicate where it was not caught.

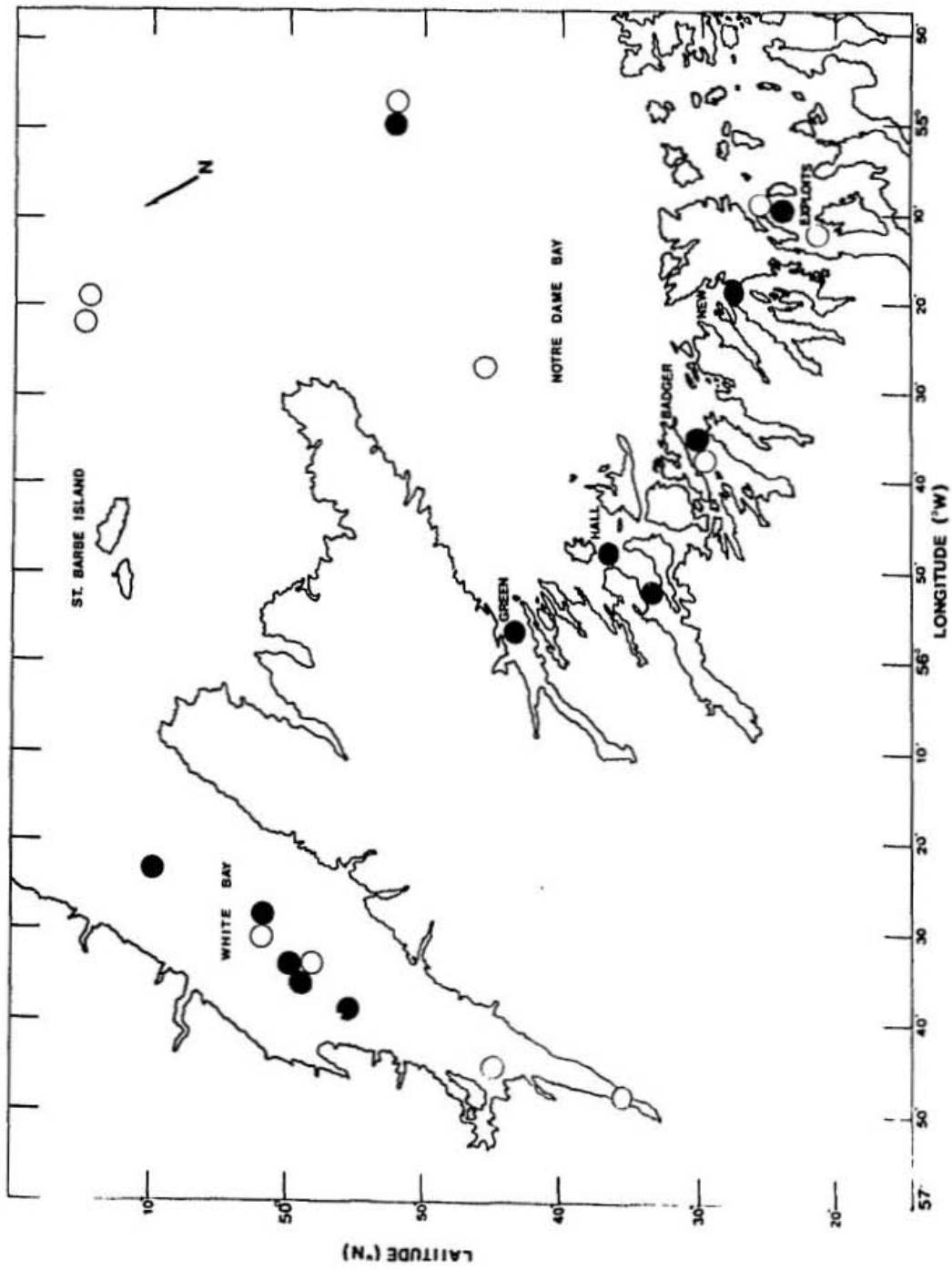

ST. BARBE ISLAND
WHITE BAY
NOTRE DAME BAY
GREEN
HALL
BADGER
NEW
EXPLOITS
N
LONGITUDE (°W)
LATITUDE (°N)

Figure 5: Map of Bonavista, Trinity and Conception Bays showing station locations. Black circles indicate where *B. nobilis* was caught and open circles indicate where it was not caught.

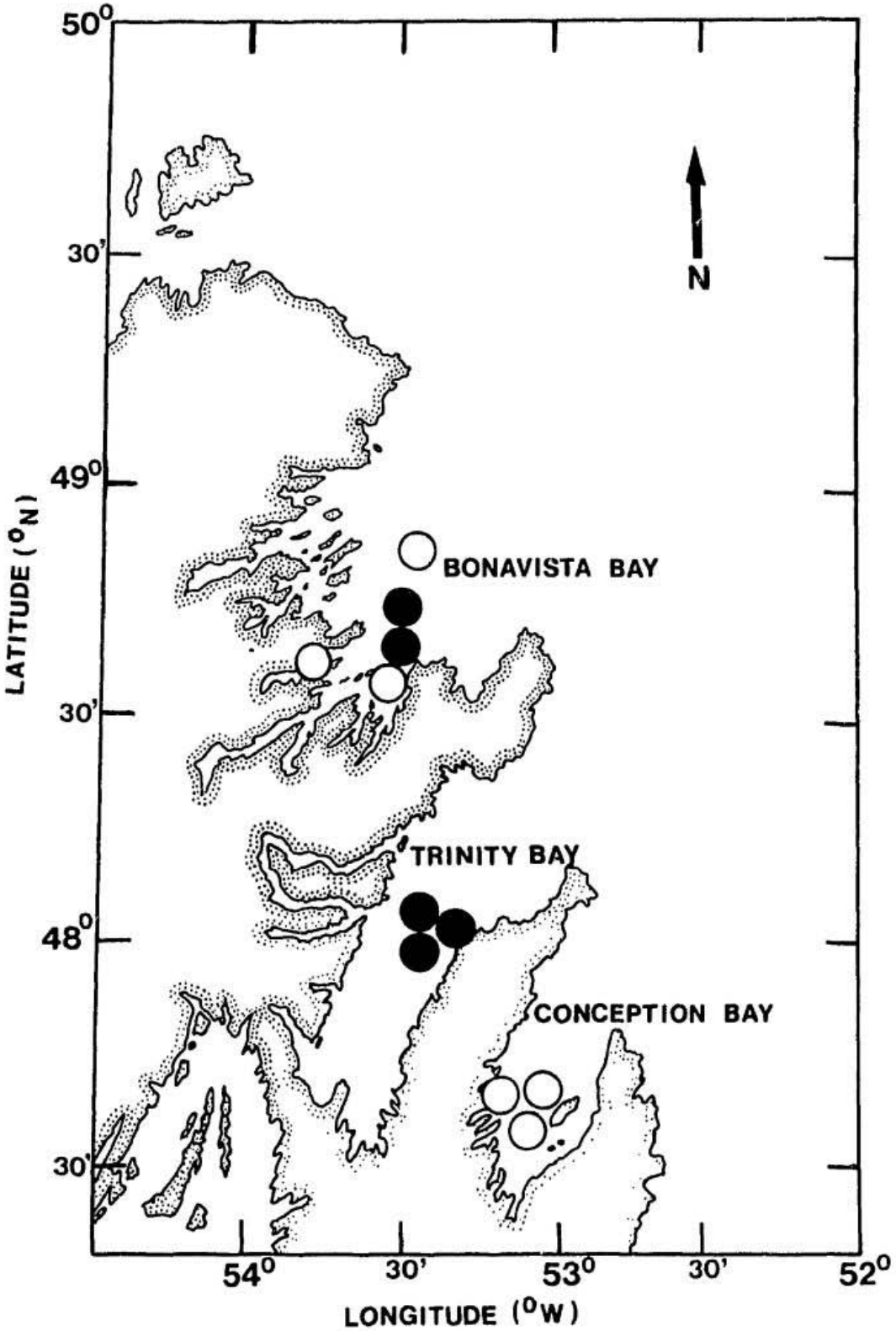

50°
30'
49°
30'
48°
30'
N
BONAVISTA BAY
TRINITY BAY
CONCEPTION BAY
LATITUDE (°N)
54°
30'
53°
30'
52°
LONGITUDE (°W)

Figure 6: Nets used in this study. The top figure shows the bongo nets and the bottom figure shows the Isaacs-Kidd Midwater Trawl. The location of the VEMCO transmitter is indicated on the figures. When the Benthos time-depth recorder was used, it was attached at the same location as the transmitter.

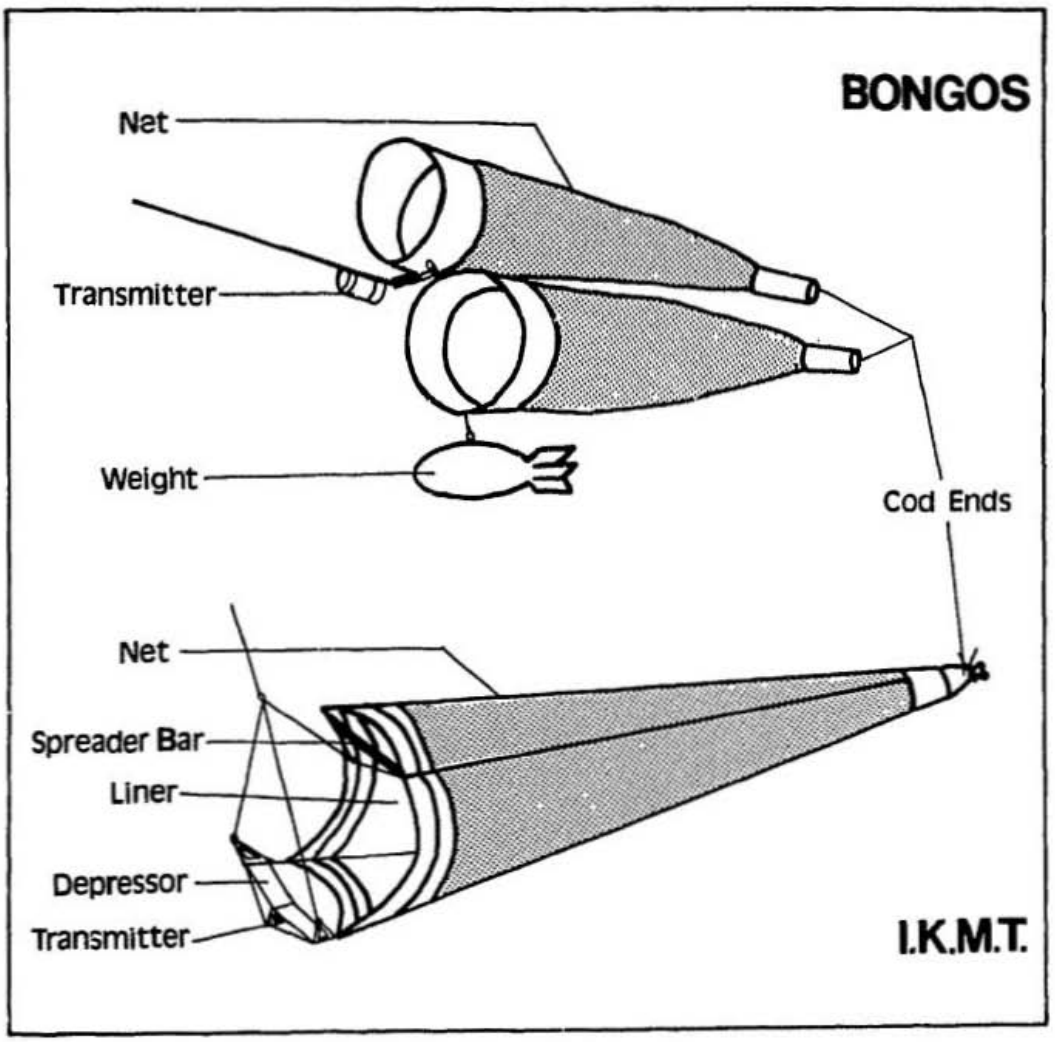

BONGOS
Net
Transmitter
Weight
Cod Ends
Net
Spreader Bar
Liner
Depressor
Transmitter
I.K.M.T.

Figure 7: Length-frequency histograms of *B. nobilis* caught with the three different nets used in this study. Figure 7a (n = 10,811) shows the length-frequency histogram for samples collected with the bongo nets, Figure 7b (n = 2,863) is from samples collected with the six foot IKMT, and Figure 7c (n = 16,830) is from samples collected with the ten foot IKMT.

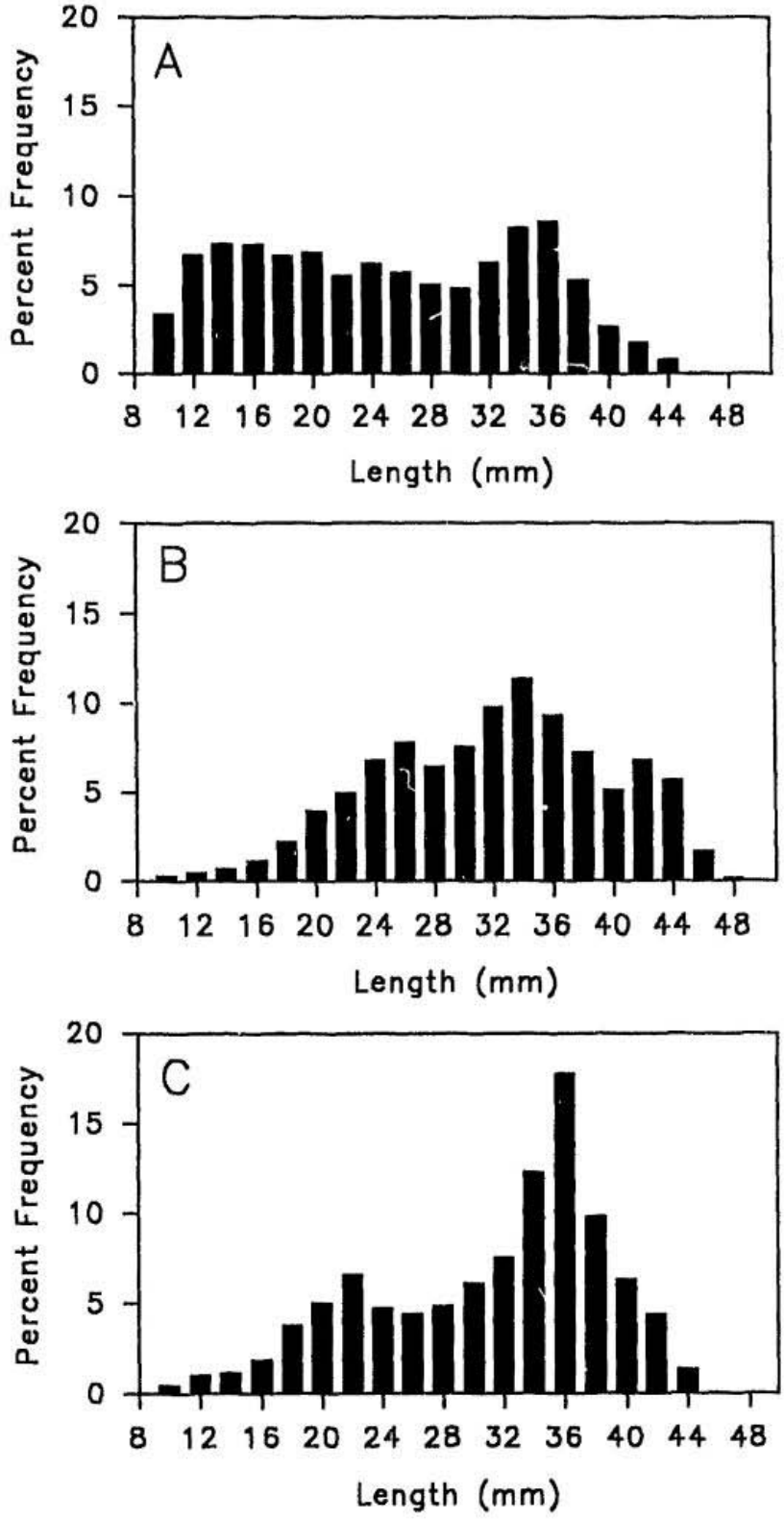

A
B
C
Percent Frequency
Length (mm)
0
5
10
15
20
8
12
16
20
24
28
32
36
40
44
48

Figure 8: The percent frequency of juveniles, males and females caught with the three different types of nets used in this study. The overall sample size was 30,504: 16,830 individuals were caught with the ten foot IKMT, 10,811 were caught with the bongo nets and 2,863 were caught with the six foot IKMT.

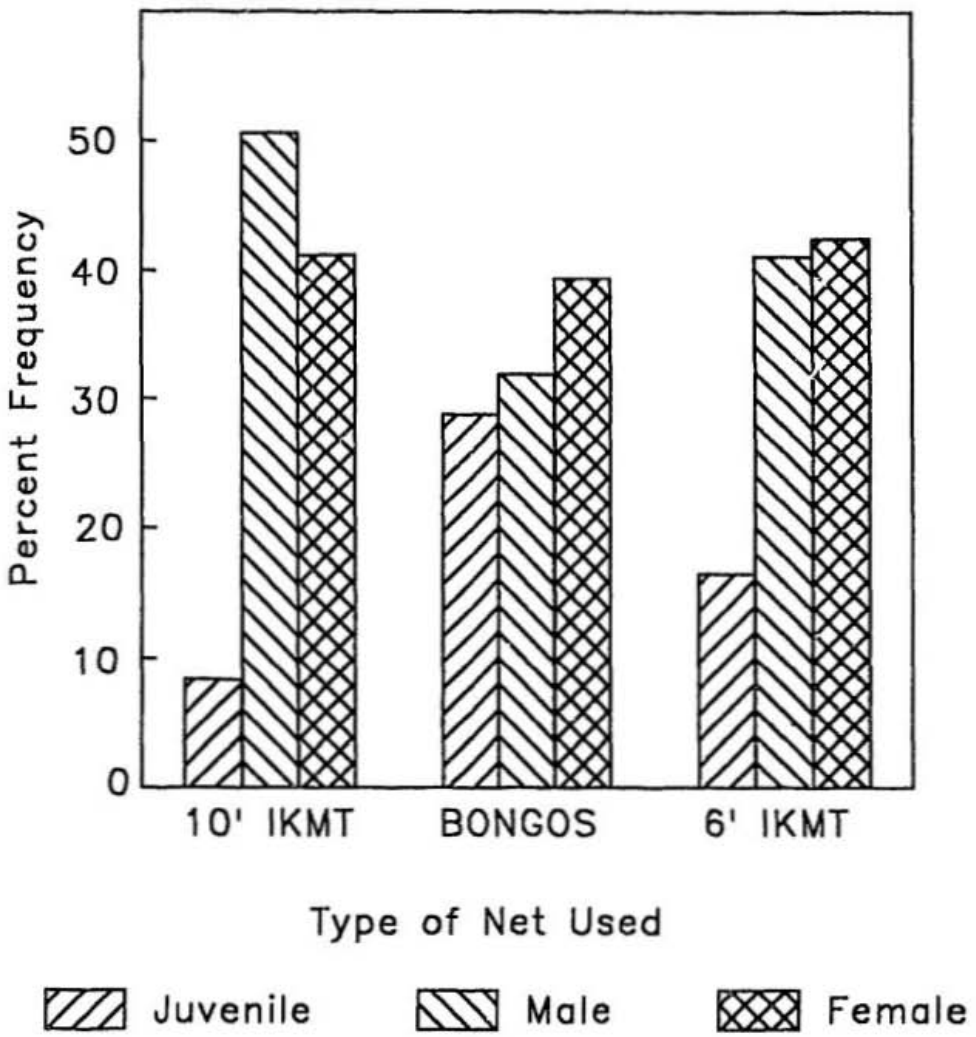
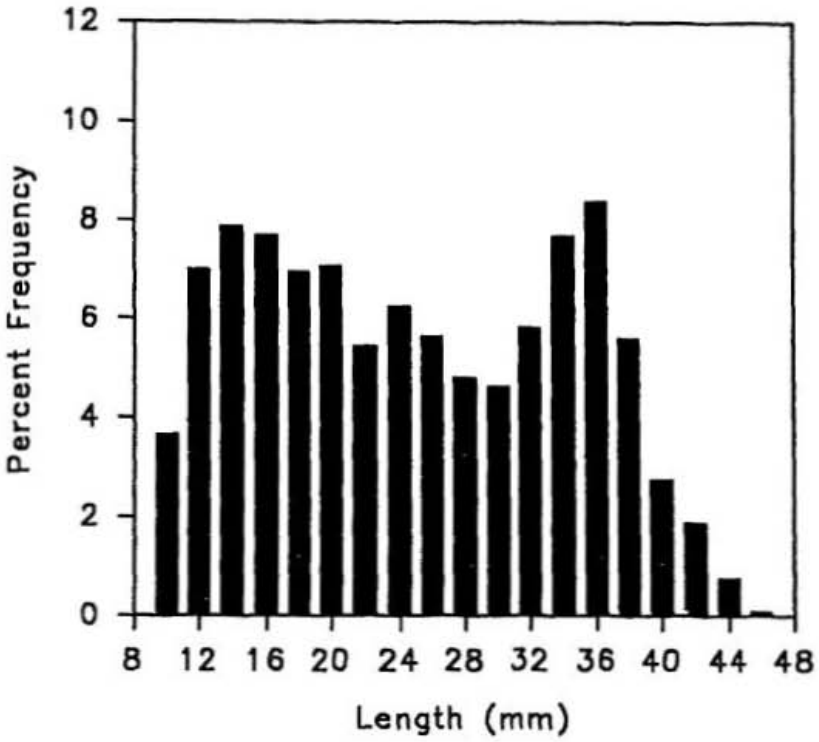

Percent Frequency
50
40
30
20
10
0
10' IKMT
BONGOS
6' IKMT
Type of Net Used
Juvenile
Male
Female

Figure 9: The length-frequencies of *B. nobilis* caught in horizontal and oblique tows using the bongo nets. Only the lengths of mysids collected on the Baffin 87-016 and Dawson 87-030 cruises were used since comparative horizontal and oblique tows were made at similar locations during these cruises. The overall sample size was 7,726: 6,788 individuals were caught in horizontal tows and 938 were caught in oblique tows.


Percent Frequency
0
2
4
6
8
10
12
8 12 16 20 24 28 32 36 40 44 48
Length (mm)

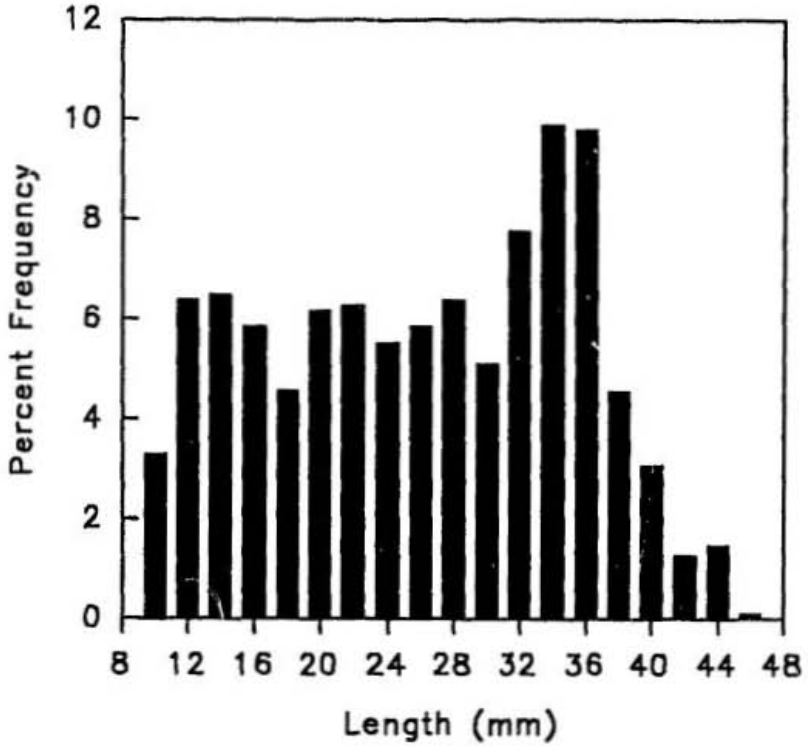

Percent Frequency
0
2
4
6
8
10
12
8 12 16 20 24 28 32 36 40 44 48
Length (mm)

Figure 10: The average catch rates (mysids per minute per m^2 of net mouth opening) of juvenile, male and female *B. nobilis* at different distances (m) above the bottom. Error bars indicate standard deviations.

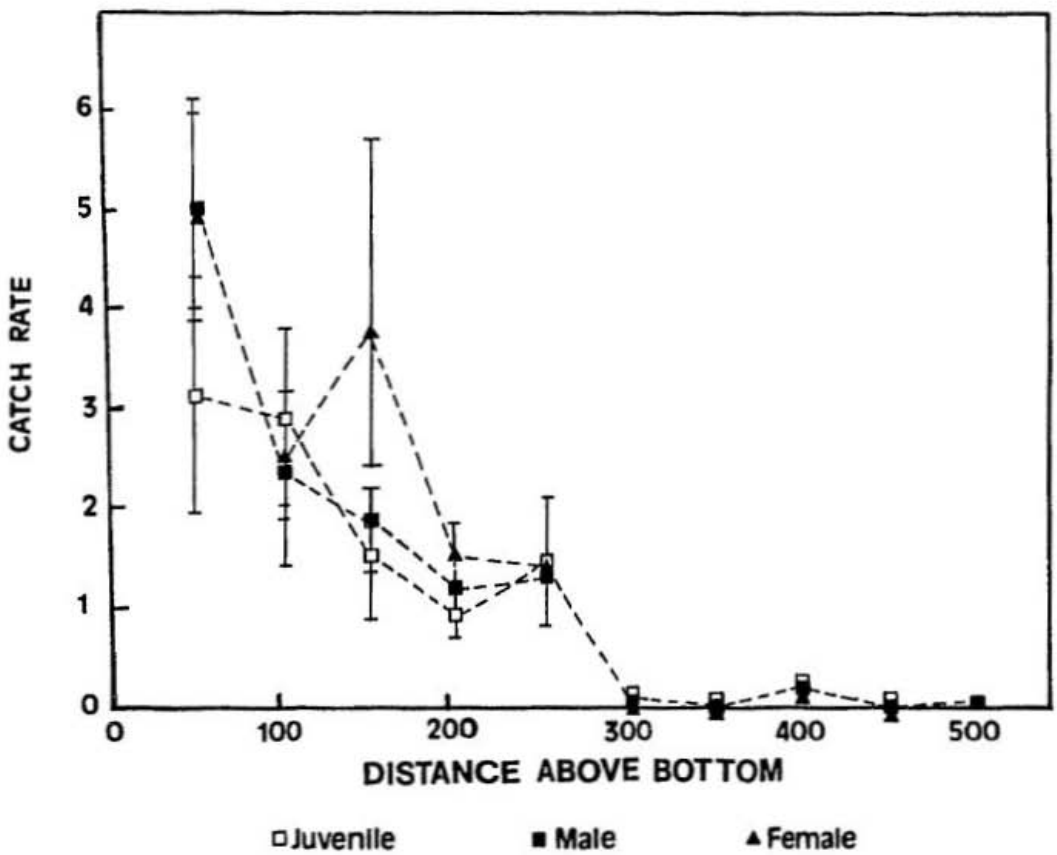

CATCH RATE
0
1
2
3
4
5
6
0
100
200
300
400
500
DISTANCE ABOVE BOTTOM
□ Juvenile
■ Male
▲ Female

Figure 11: The average catch rates (mysids per minute per m^2 of net mouth opening) of juvenile, immature and mature *B. nobilis* at different distances (m) above the bottom. Error bars indicate standard deviations.

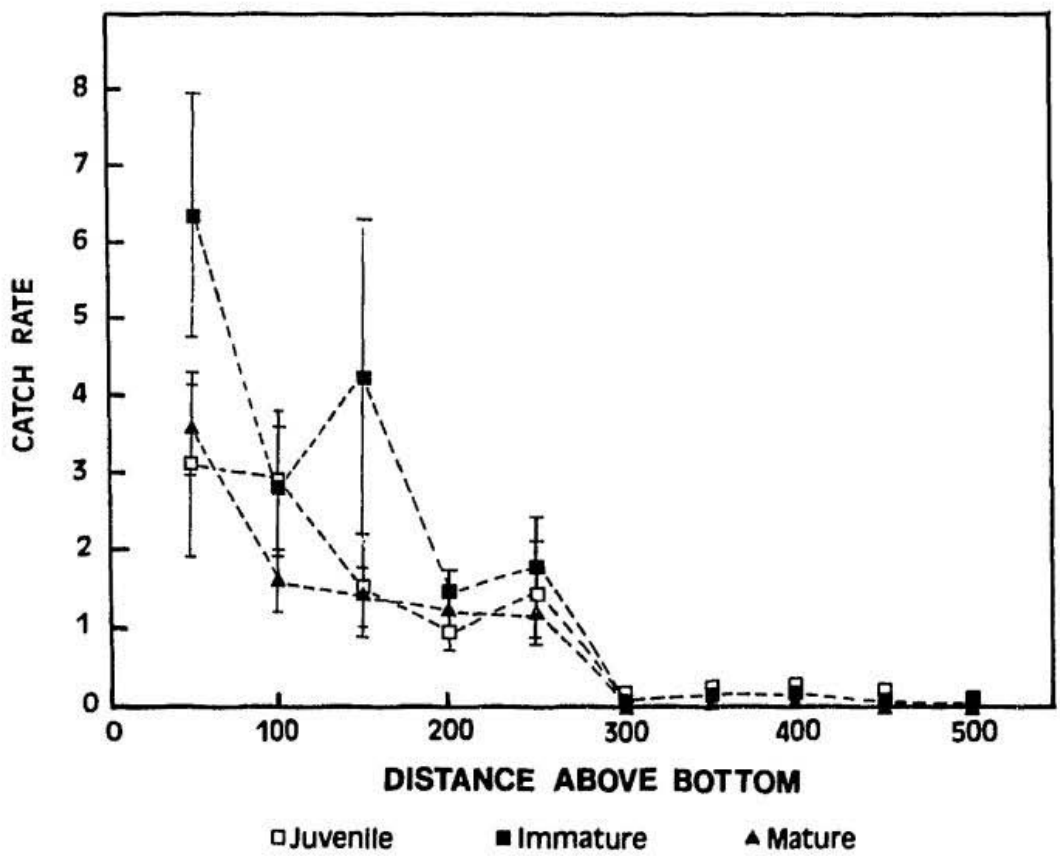

CATCH RATE
0
1
2
3
4
5
6
7
8
0
100
200
300
400
500
DISTANCE ABOVE BOTTOM
Juvenile
Immature
Mature

Figure 12: The length-frequency distributions of *B. nobilis* in White Bay in November 1986 (Figure 12a), May 1987 (Figure 12b) and August 1987 (Figure 12c). In Figure 12a n=78, in 12b n=529 and in 12c n=151.

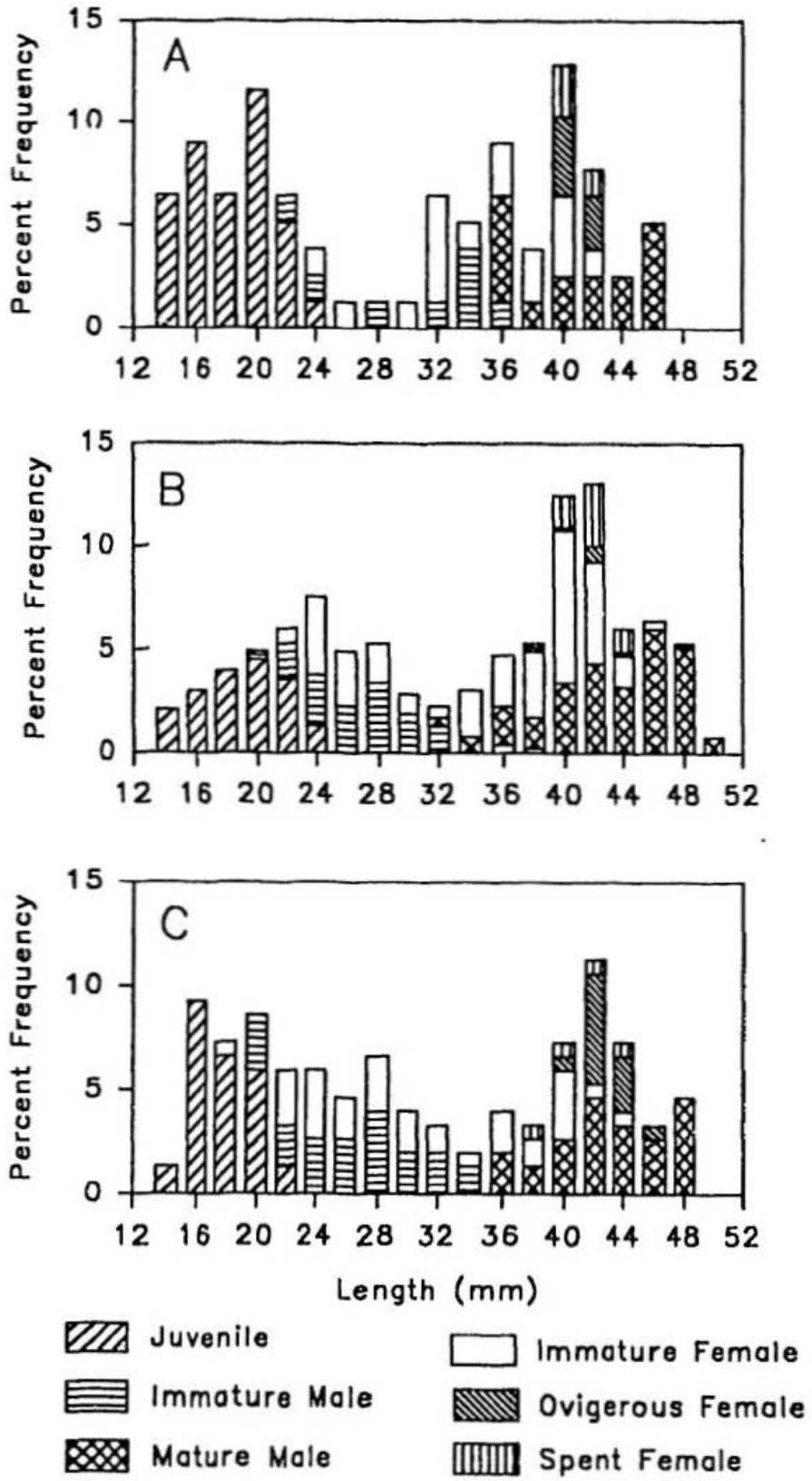

A
B
C
Percent Frequency
15
10
5
0
12 16 20 24 28 32 36 40 44 48 52
Length (mm)
Juvenile
Immature Male
Mature Male
Immature Female
Ovigerous Female
Spent Female

Figure 13: The percent frequency of the six different life history stages of *B. nobilis* in White Bay in November 1986 (Figure 13a), May 1987 (Figure 13b) and August 1987 (Figure 13c). Only data from mysids collected by horizontal bongo tows less than 100m above the bottom were used in this figure. Juv=juveniles, I.M.=immature males, M.M.=mature males, I.F.=immature females, O.F.=ovigerous females, and S.F.=spent females.

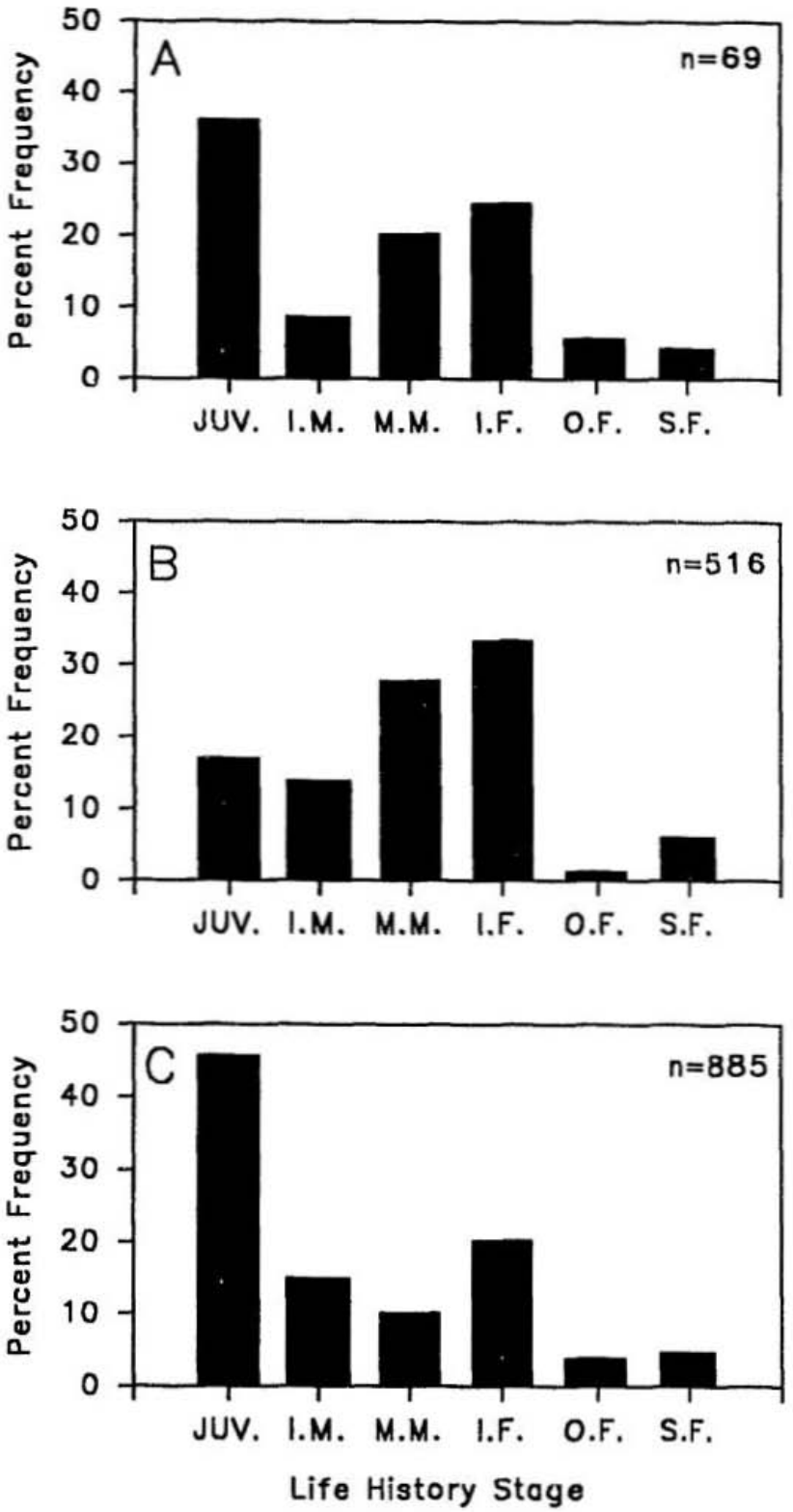

A
n=69
B
n=516
C
n=885
Percent Frequency
50
40
30
20
10
0
JUV.
I.M.
M.M.
I.F.
O.F.
S.F.
Life History Stage

Figure 14: The relationship between the log of the number of stage 1 larvae and the log of the length of the ovigerous females cubed. The regression lines calculated by Mauchline (1980) for coastal and epipelagic mysids and meso- and bathypelagic mysids are included on the figure.

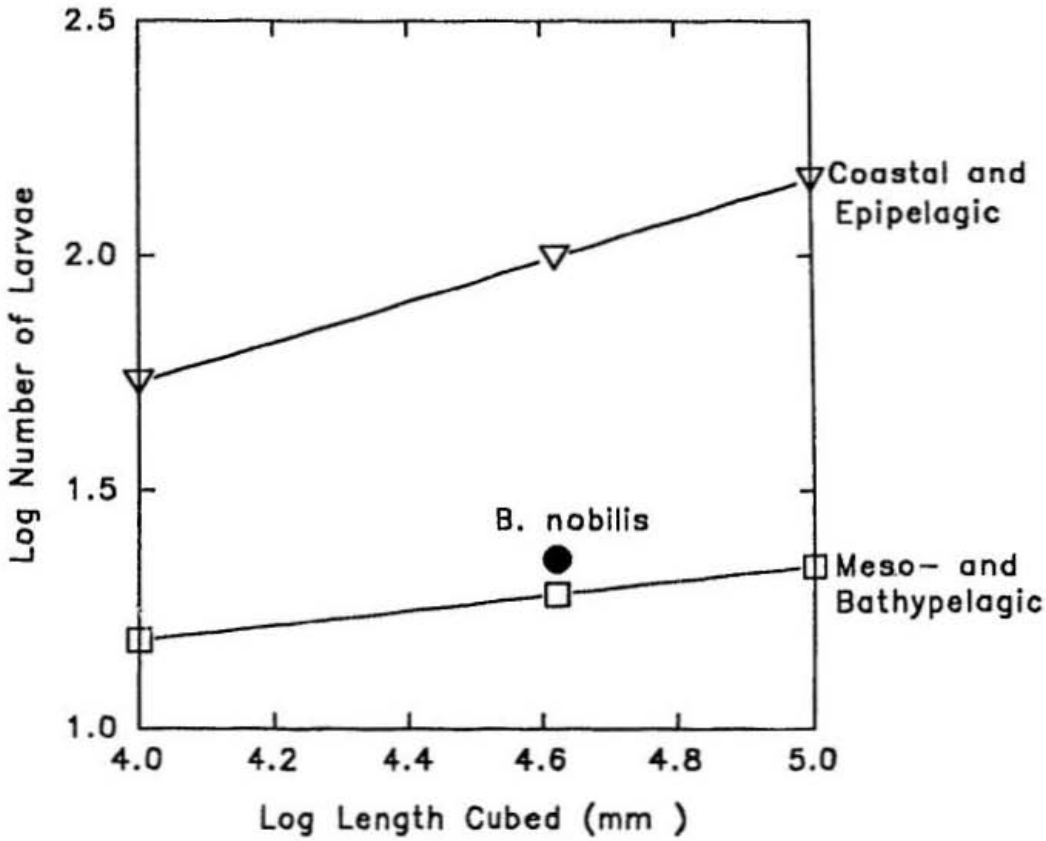

2.5
2.0
1.5
1.0
Log Number of Larvae
4.0
4.2
4.4
4.6
4.8
5.0
Log Length Cubed (mm)
Coastal and
Epipelagic
B. nobilis
Meso- and
Bathypelagic

Figure 15: An ovigerous female *B. nobilis* with a marsupium containing stage 2 larvae. This figure shows the orientation of the larvae in the marsupium. The majority of larvae are facing posteriorly but the larvae which are proximal to the thorax of the female are facing anteriorly.

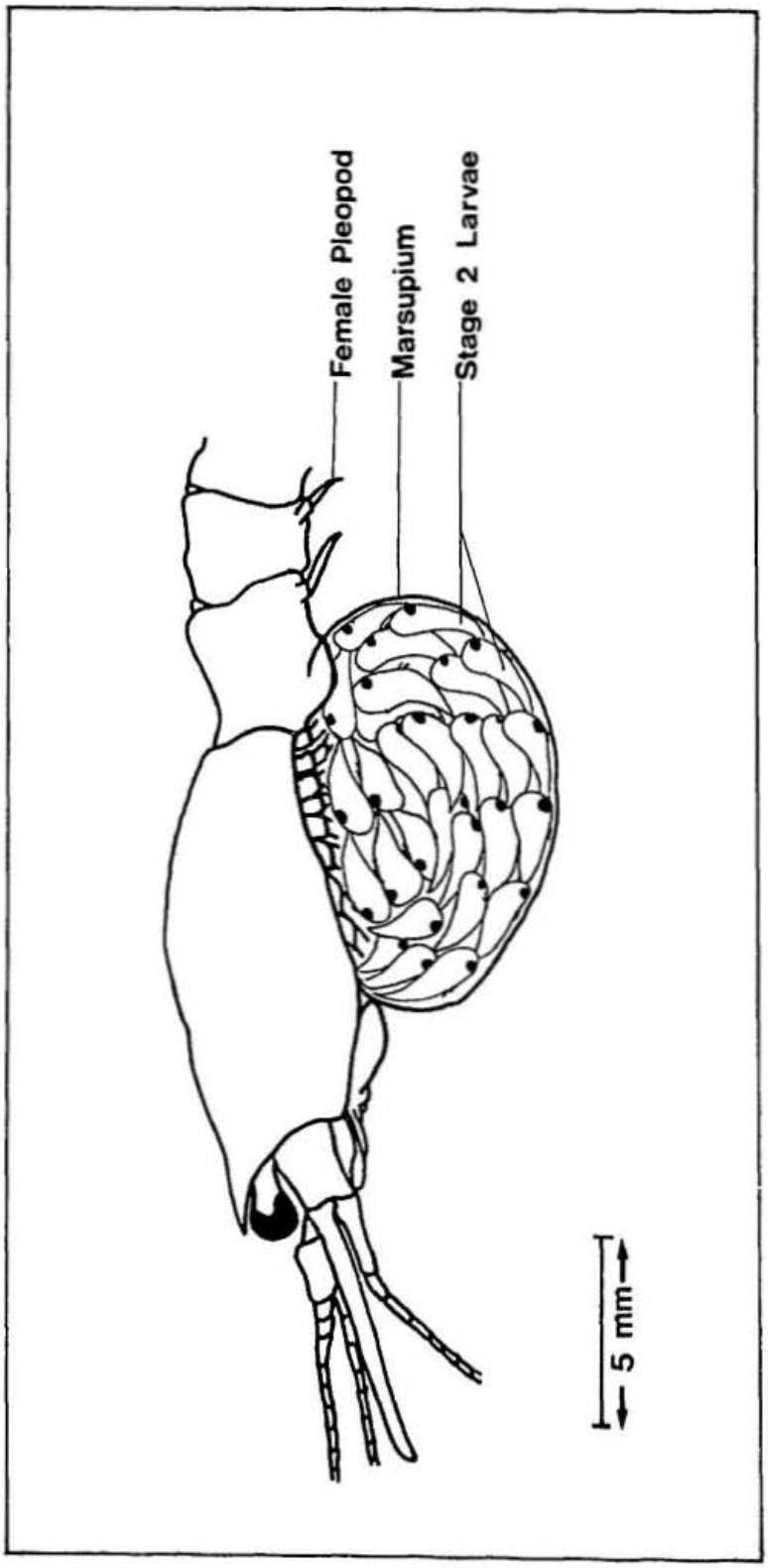

Female Pleopod
Marsupium
Stage 2 Larvae
5 mm

Figure 16: *Thalassomyces boschmai* on the carapace of an immature male *B. nobilis*.

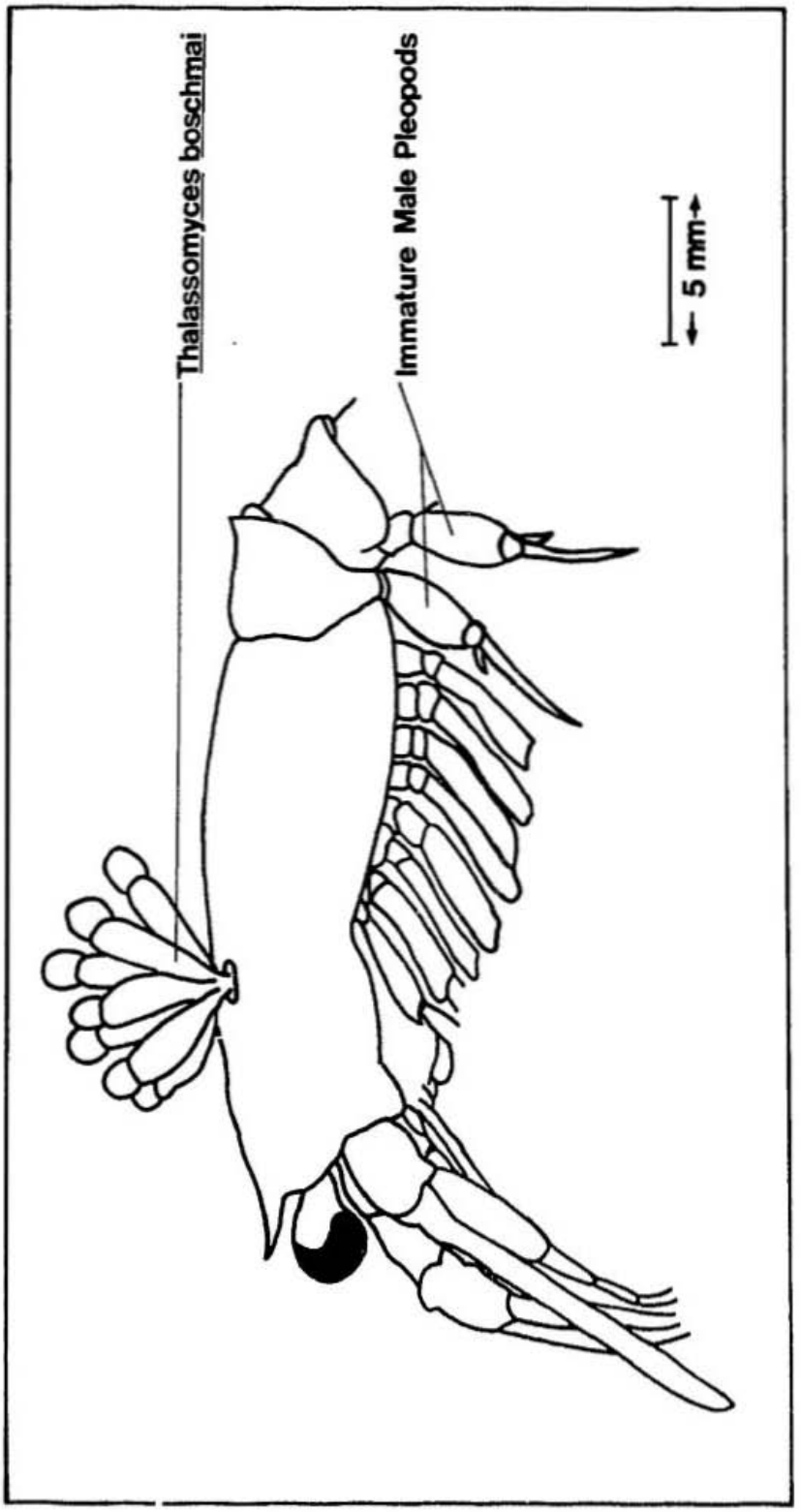

Thalassomyces boschmai
Immature Male Pleopods
5 mm

Figure 17: The structure of the parasite *Thalassomyces boschmai*.

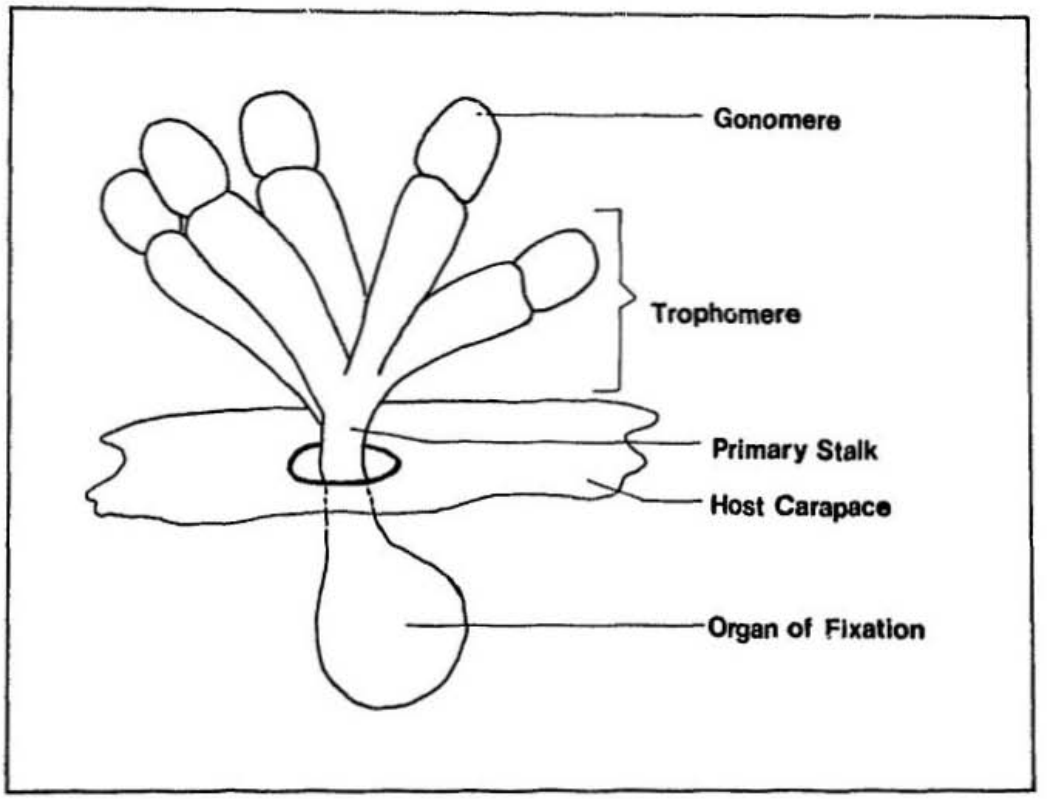

Gonomere
Trophomere
Primary Stalk
Host Carapace
Organ of Fixation

Figure 18: Scanning electron micrograph of *T. boschmai* from the carapace of an immature male *B. nobilis* from Station 1902 in Trinity Bay.

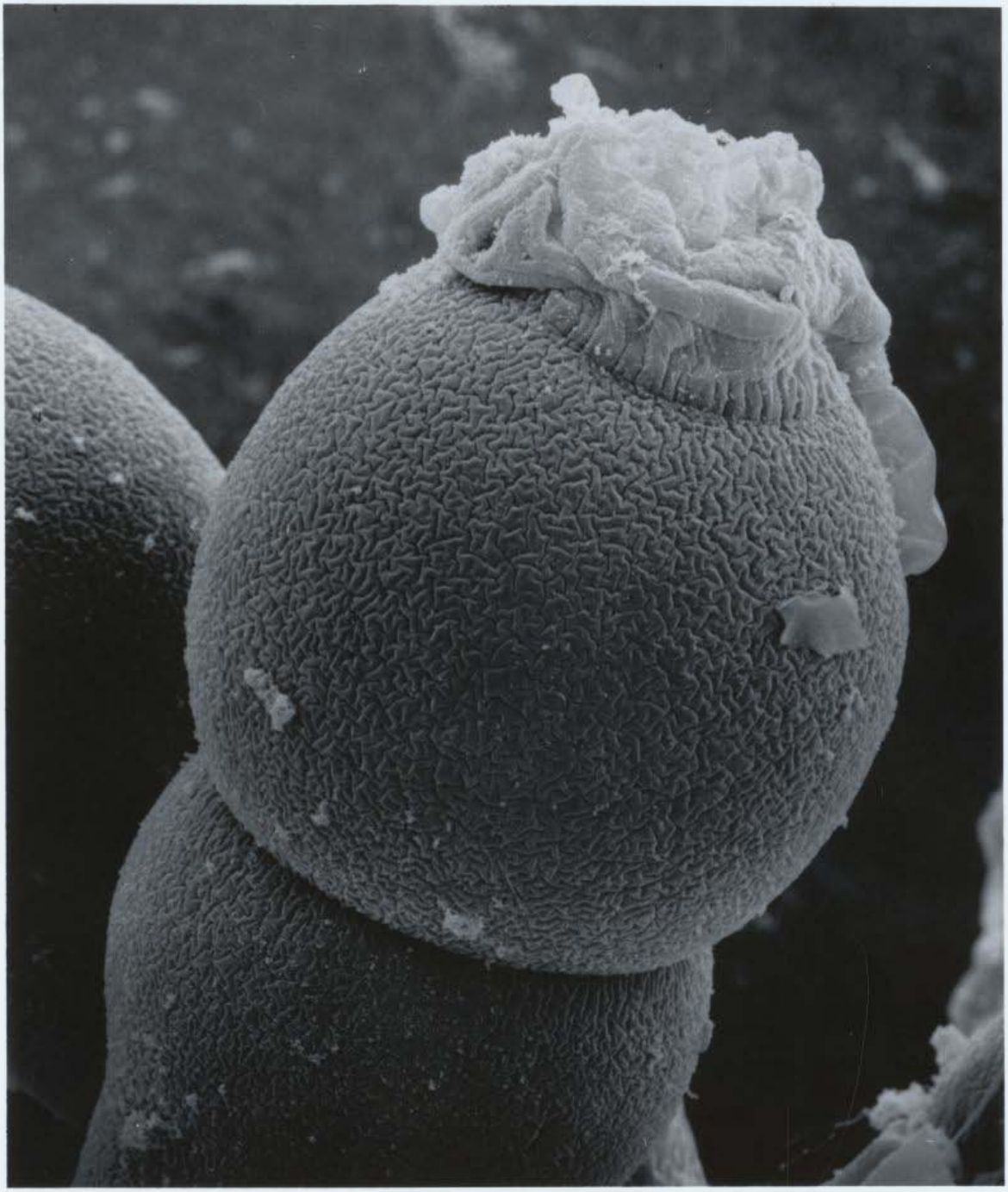


Figure 19: Scanning electron micrograph of *T. boschmai* from the carapace of an immature male *B. nobilis* from station 1905 in Trinity Bay.

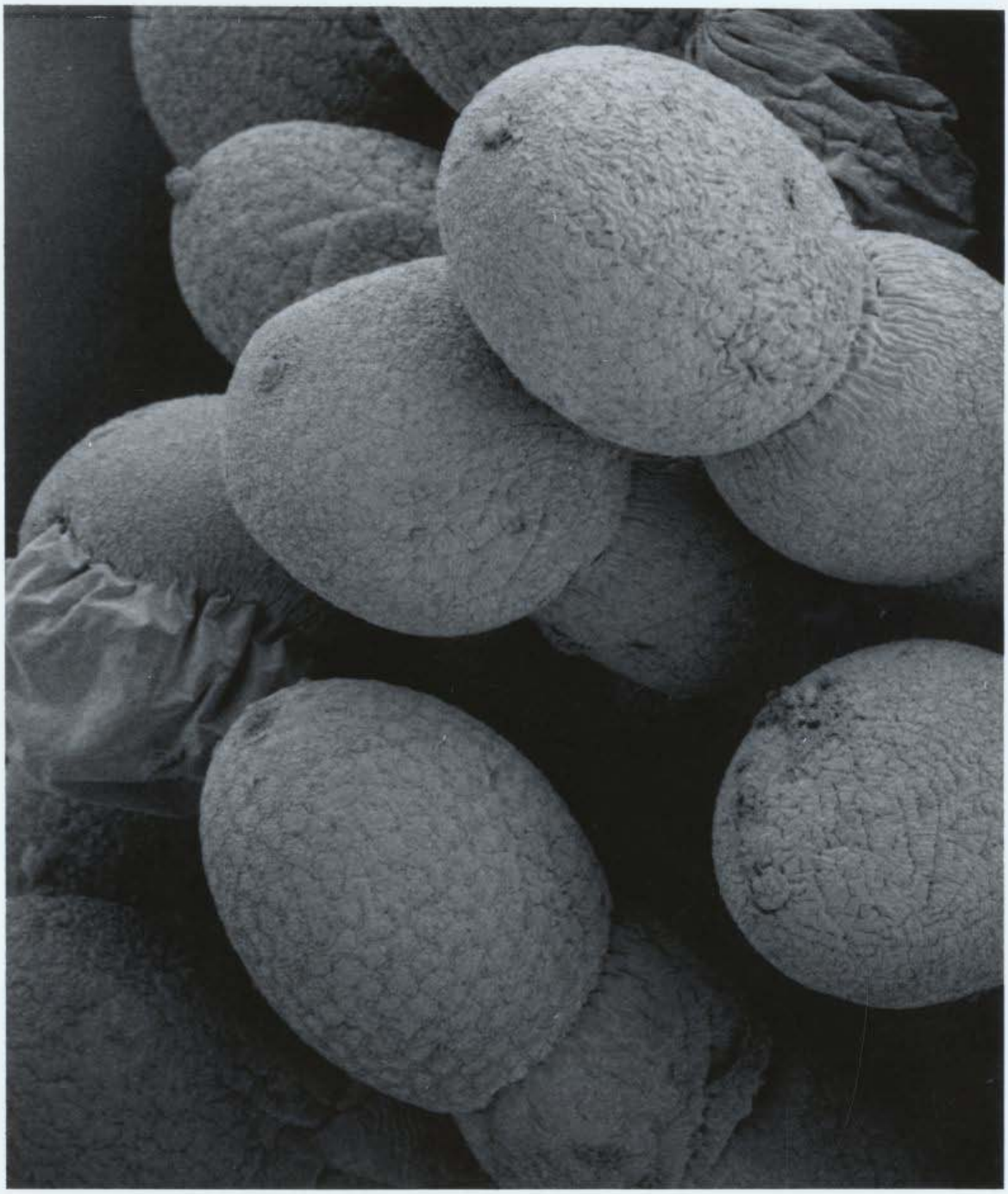
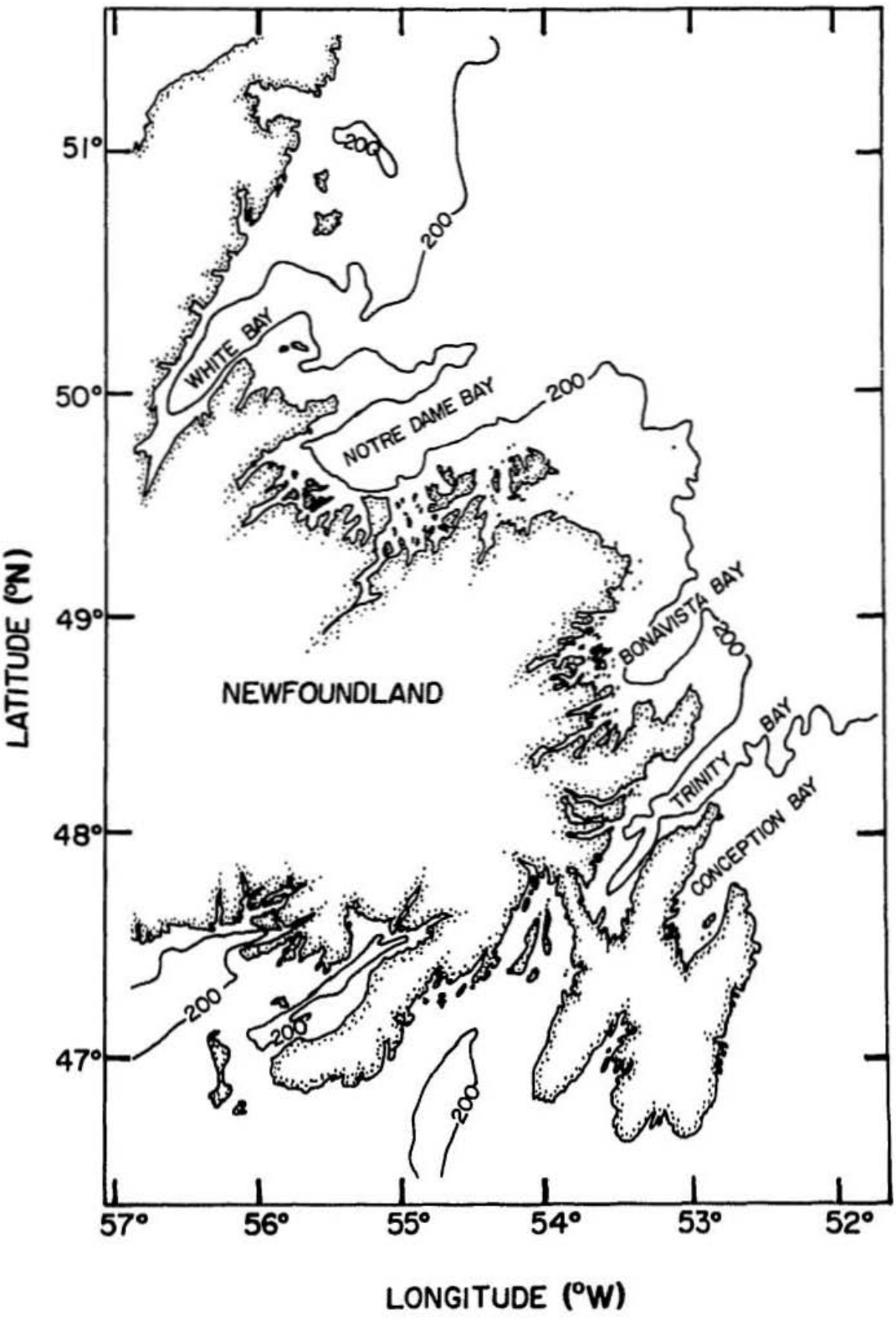


Figure 20: Map of the northeast coast of Newfoundland showing the 200m contour line.


51°
50°
49°
48°
47°
57°
56°
55°
54°
53°
52°
LATITUDE (°N)
LONGITUDE (°W)
NEWFOUNDLAND
WHITE BAY
NOTRE DAME BAY
BONAVISTA BAY
TRINITY BAY
CONCEPTION BAY
200
200
200
200
200
200